Automatically Repairing Broken Workflows for Evolving GUI Applications

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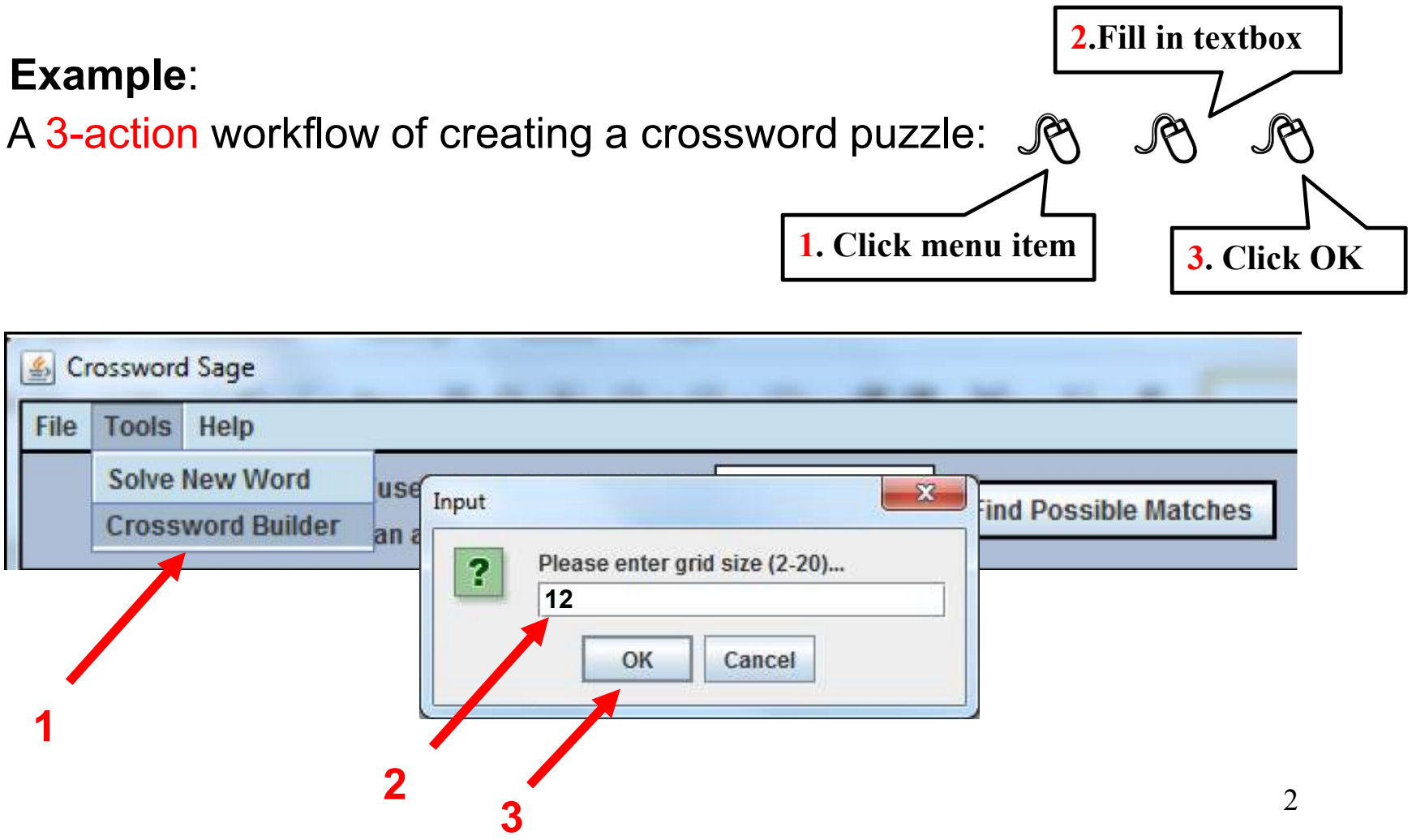
End-user's workflow

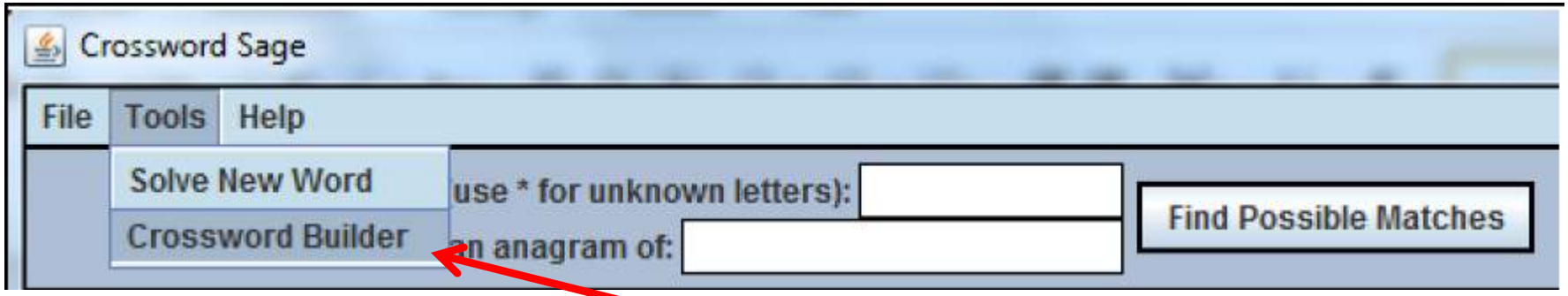
A **workflow** = A sequence of **UI actions** for a specific task

Example:

A 3-action workflow of creating a crossword puzzle:

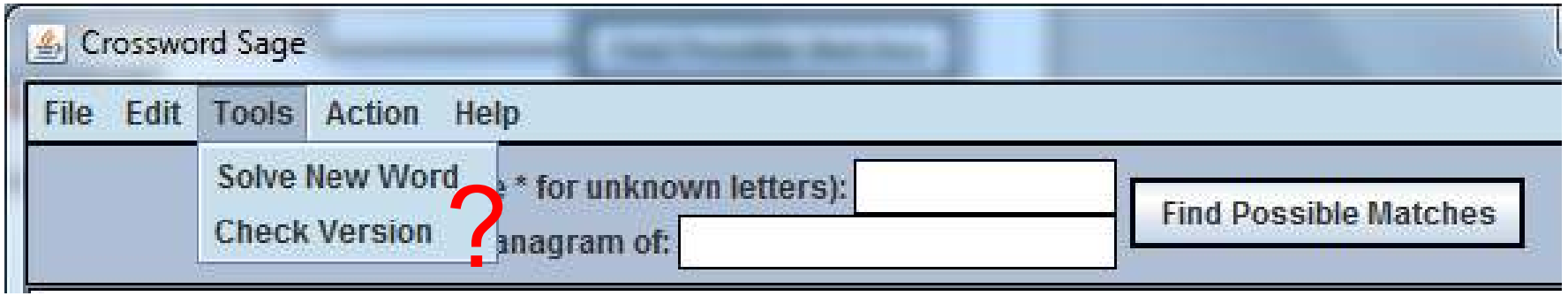


GUI evolution can break workflows



Version 0.3

(the first action in creating a puzzle)

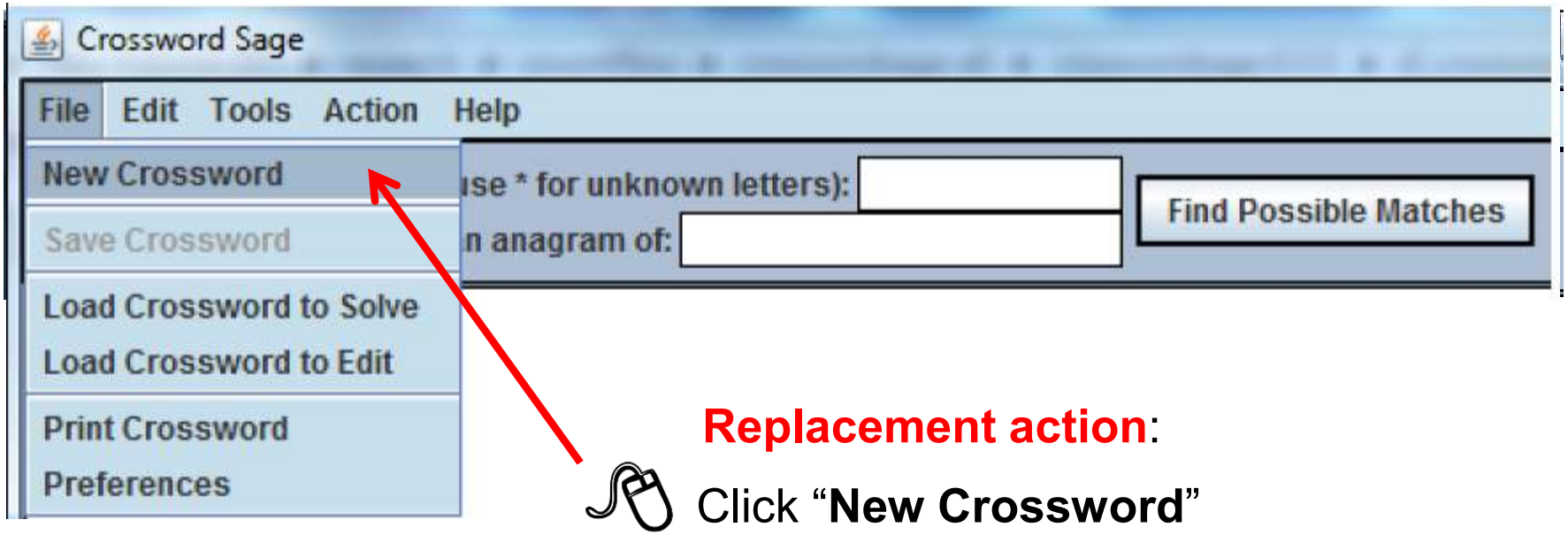


Version 0.35

The workflow is broken!

Goal: repair a broken workflow

- Suggest a "**replacement action**" for a broken action
  - **No** change to the code
  - Help users perform the **same** task, but **adapt** to the new GUI



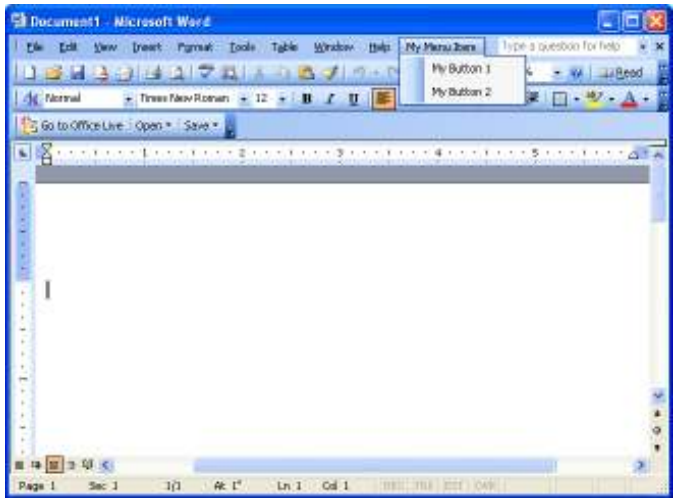
Replacement action:

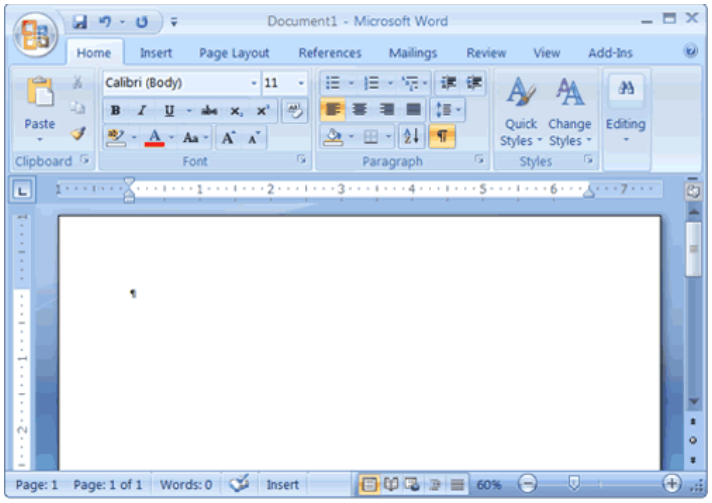
Click "**New Crossword**"

(Suggested by our technique: **FlowFixer,** since both invoke method "**`showCrosswordBuilder`**")

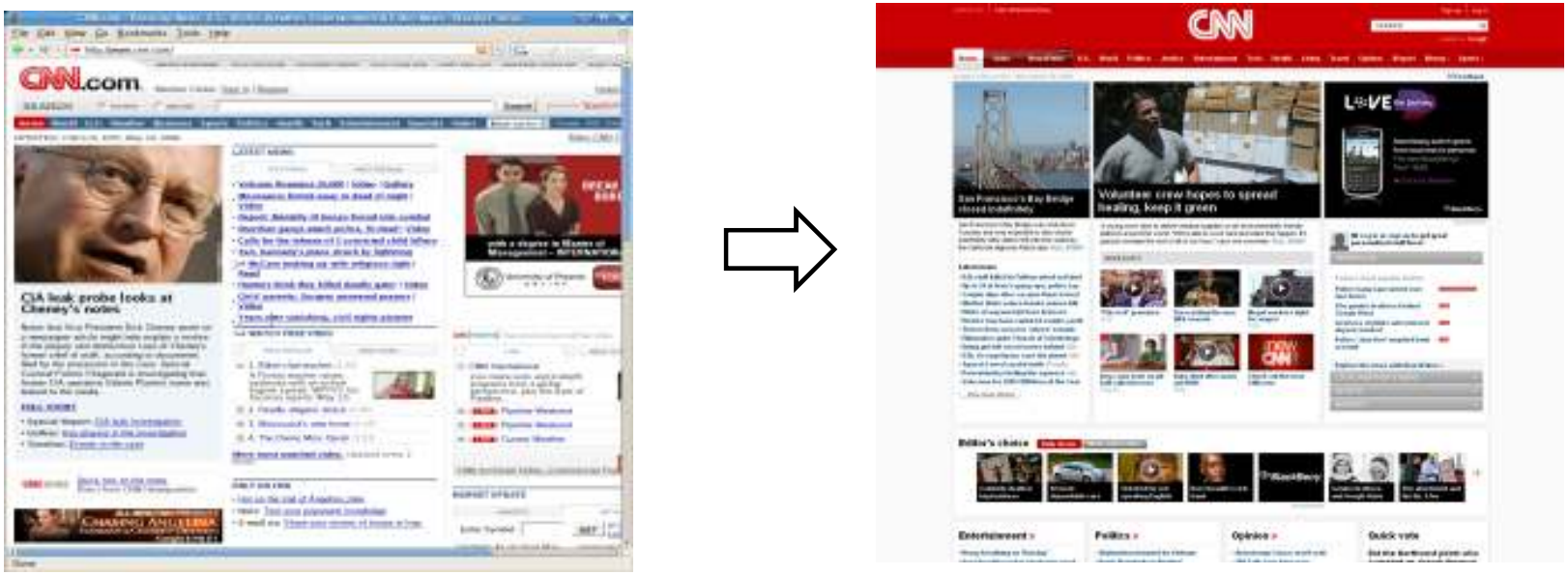
GUIs keep evolving all the time

GUIs keep evolving all the time





GUIs keep evolving all the time



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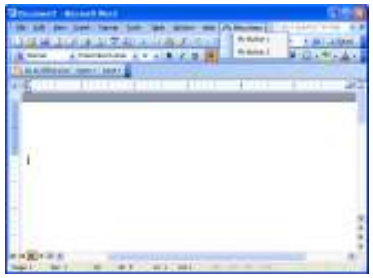
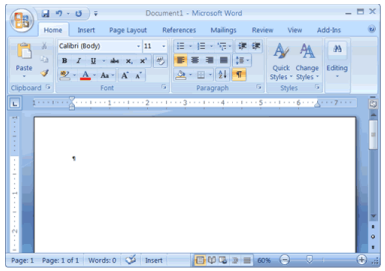
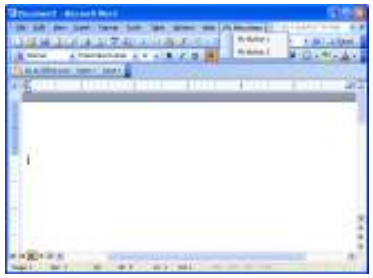
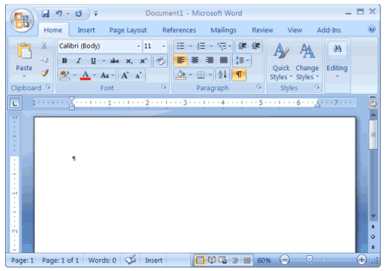
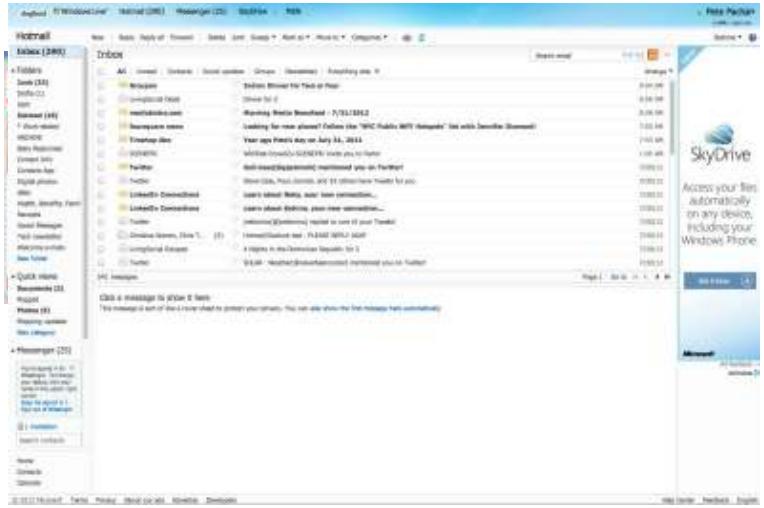


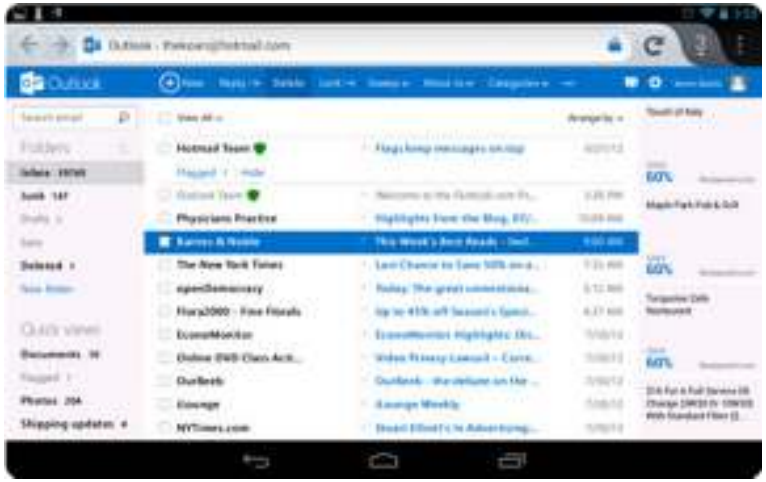


GUIs keep evolving all the time









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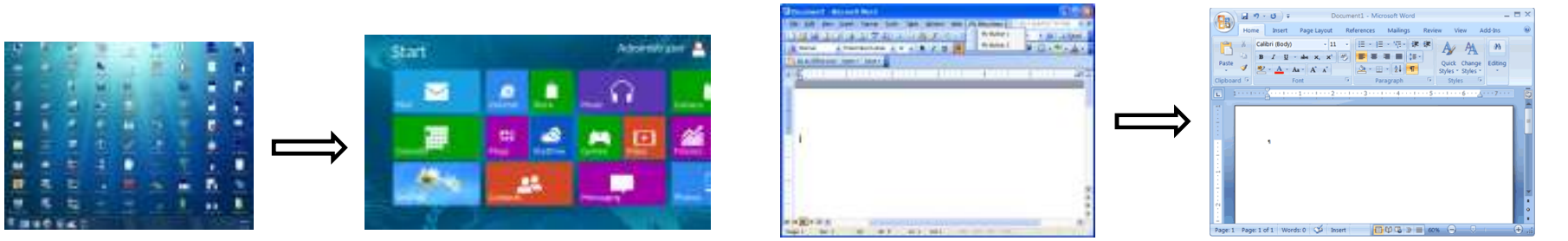


GUI evolution can break workflows!

Broken workflows in practice

- **Affect user experience** (focus of this talk)

Microsoft Office Community

100+ posts

Example: the ribbon UI in Office 2007

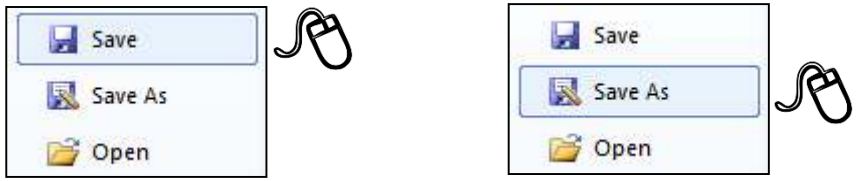
- **Impact automated testing**

- mimic workflows
- **30 – 70%** of them are broken in GUI evolution [Memon'03, Grechanik'09, Daniel'11]

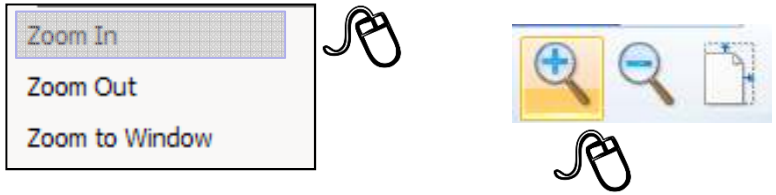
Tedious and challenging to resolve them manually

The "action semantics" challenge

- A UI action's effect cannot be observed statically
- Repairing broken workflows needs to:
  - distinguish actions that *look similar* but have *different results*



  - identify *different* UI actions that may perform the *same* task



Requires knowing the "what the action does"

Outline

- Problem
- Technique
- Evaluation
- Related Work
- Contributions

Key insights of FlowFixer

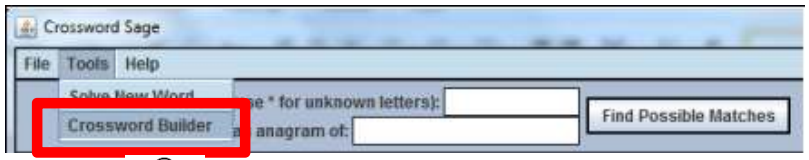
- The *underlying code* implementing the *same* functionality *stays relatively the same* between versions

- "action semantics" ≈ the invoked methods

- UI Actions invoking *similar methods* are likely to perform *similar* tasks

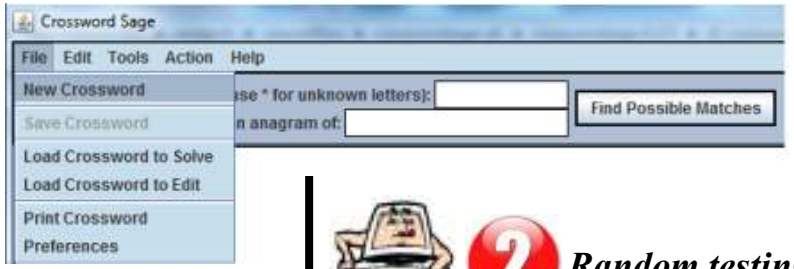
An overview of the FlowFixer technique

Old version



GUI change

New version



1 *User demonstration*

2 *Random testing*

```
actionPerformed()
showCrosswordBuilder()
...
```

3 *Method matching*

Weight

1. Click "New Crossword" ~~1/3~~ 1

```
actionPerformed()
showCrosswordBuilder()
...
```

2. Click "Save Crossword" 1/3

```
actionPerformed()
saveCrossword()
...
```

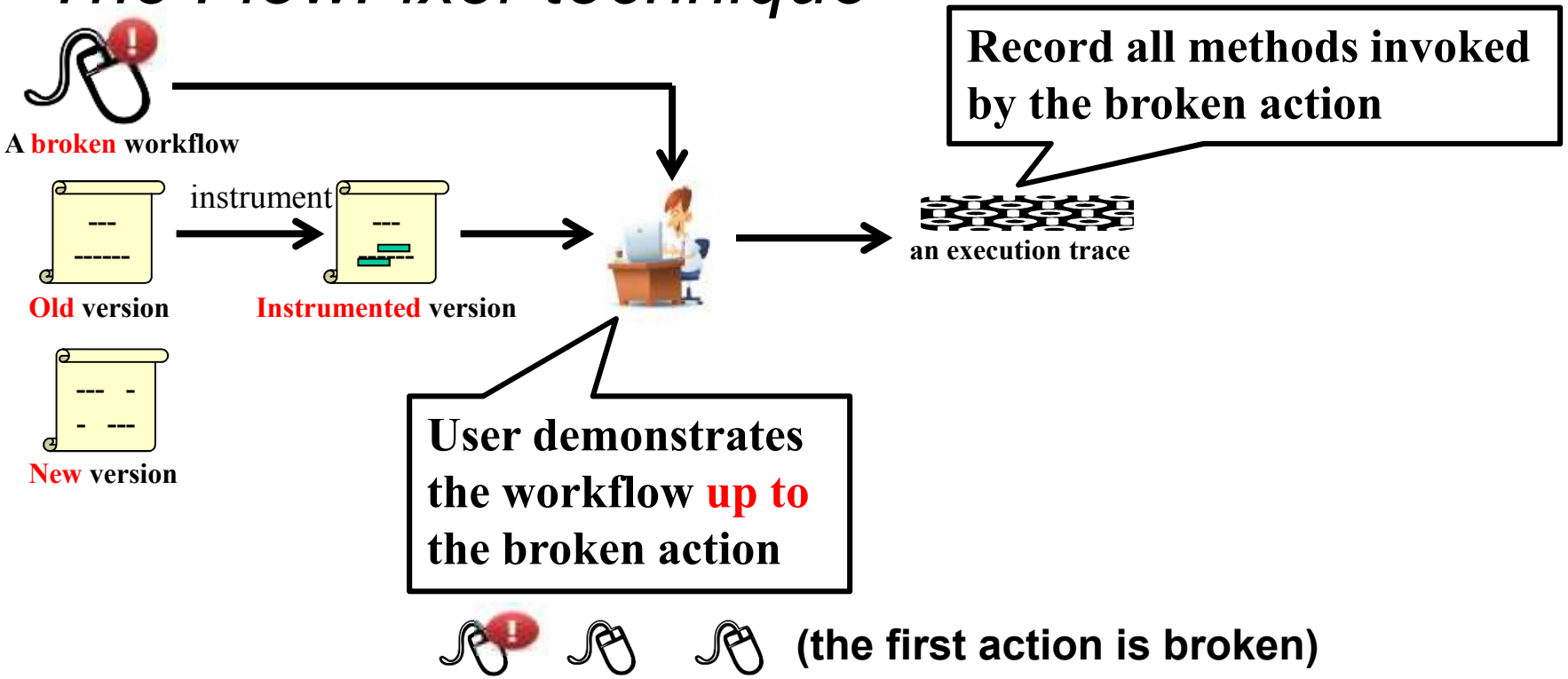
3. Click "Solve New Crossword" 1/3

```
actionPerformed()
crosswordSolverPanel<init>()
...
```

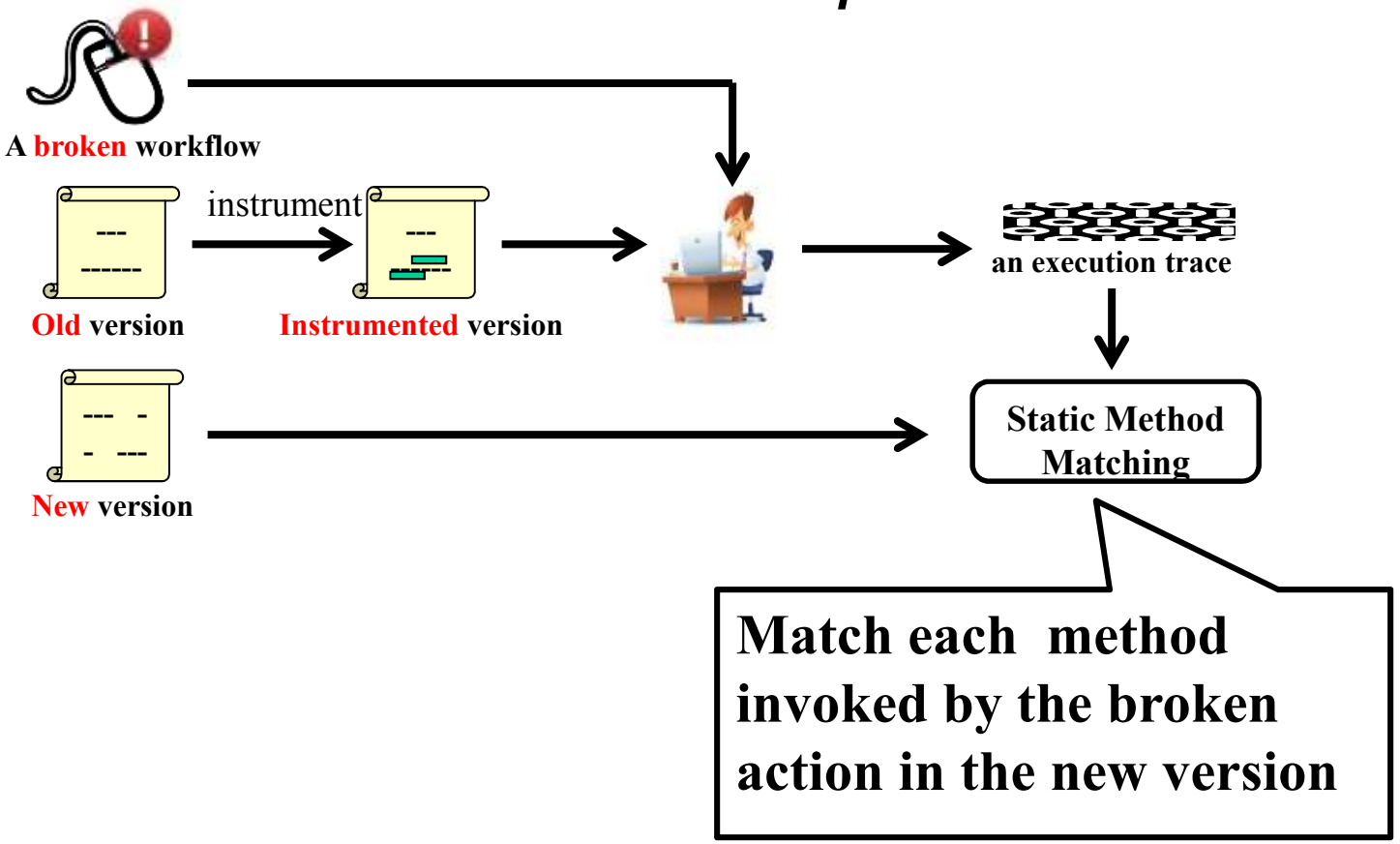
4 **Replacement actions:**

1. Click "New Crossword"
2. …

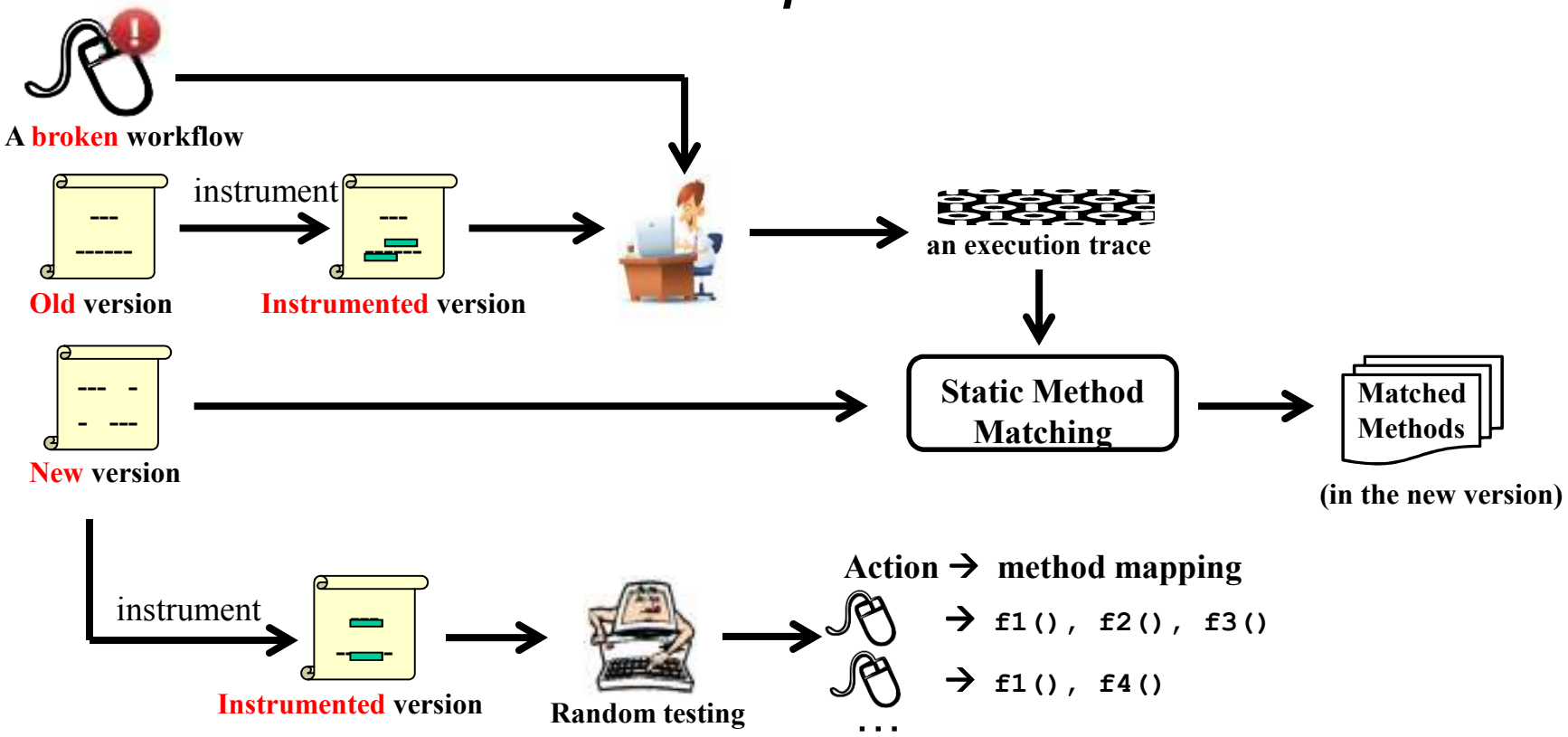
The FlowFixer technique



The FlowFixer technique

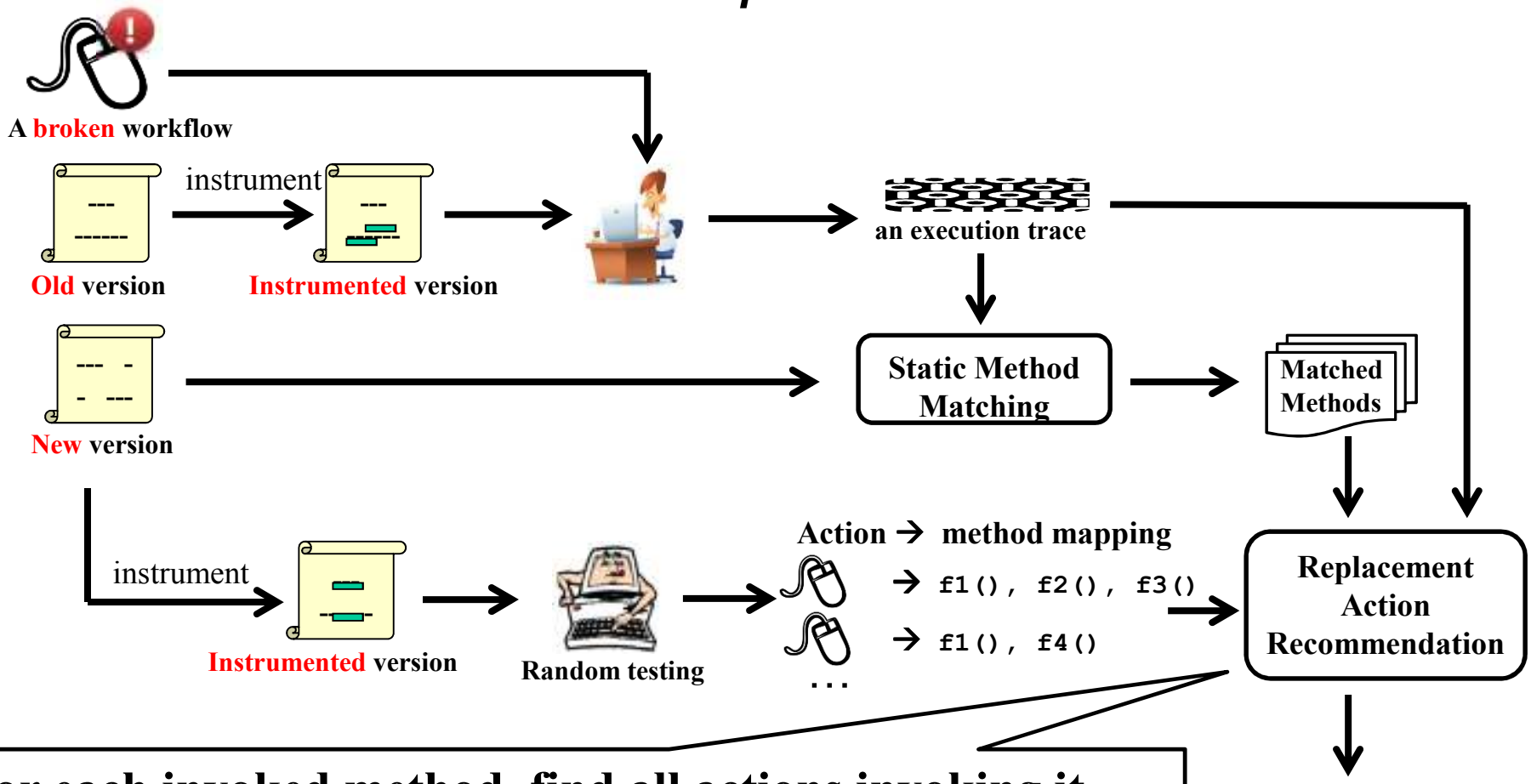


The FlowFixer technique



Randomly execute each applicable UI action, and *recursively* explore UI actions on new screens

The FlowFixer technique



For each invoked method, find all actions invoking it.

The weight of each action is *inversely proportional* to the number of all possible invoking actions.

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Research questions

- How effective is FlowFixer in repairing broken workflows?
  - Accuracy
  - Efficiency
- Comparison with a GUI-comparison-based technique [Grechanik'09]

Subject programs and broken workflows

Subject	Versions	LOC	∆LOC	#Broken workflows
Crossword	0.3 → 0.35	3,087	1,386	1
JEdit	2.5 → 2.6	32,607	5,017	1
Gantt Project	2.0.1 → 2.5.4	55,009	3,777	5
JabRef	2.0 → 2.8.1	83,447	38,992	3
Freemind	0.71 → 0.8	70,430	10,757	6

Popular software, being actively developed for 3—12 years

Non-trivial code changes

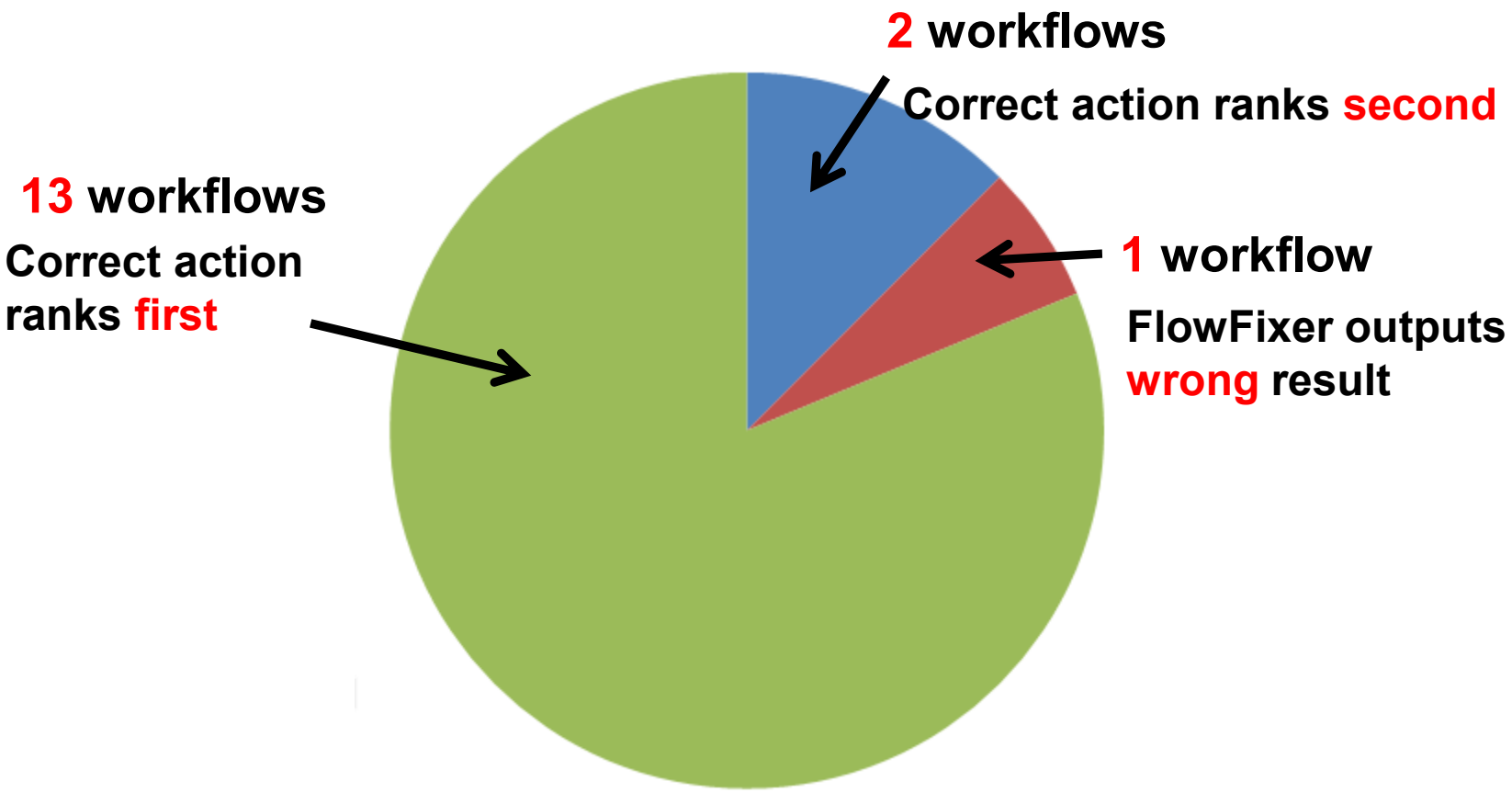
16 workflows with distinct root causes. Collected from user manual.

- Selection of broken workflows
  - **356** documented workflows, **70** are broken, **16** have **distinct** root causes
  - **Exclude** trivial UI changes, e.g.,
    - *swapping two neighboring menu items*
    - *move a button to a different location on the same panel*.

FlowFixer's accuracy

- Measured by the **absolute rank** of the **correct** actions

1. 
2. 
3. …



FlowFixer can repair 15 broken workflows

FlowFixer's efficiency

- **Random testing**
  - 27 mins per *application*

    (*A **one-time** cost, shared by different workflows*)

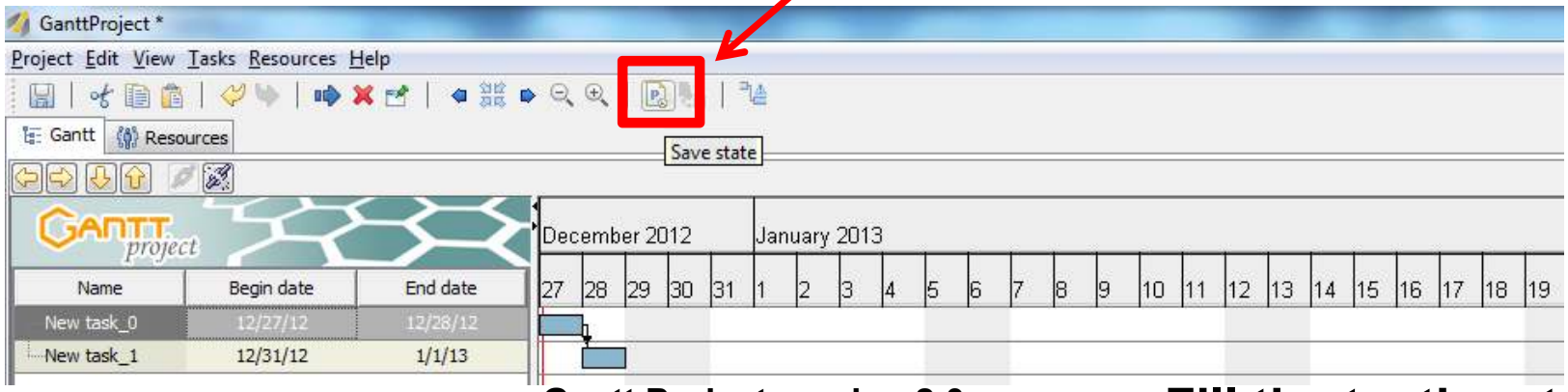
- **User demonstration**
  - **<** 1 min per workflow

    (assuming the old version is installed)

- **Action recommendation**
  - 4 mins per *workflow*

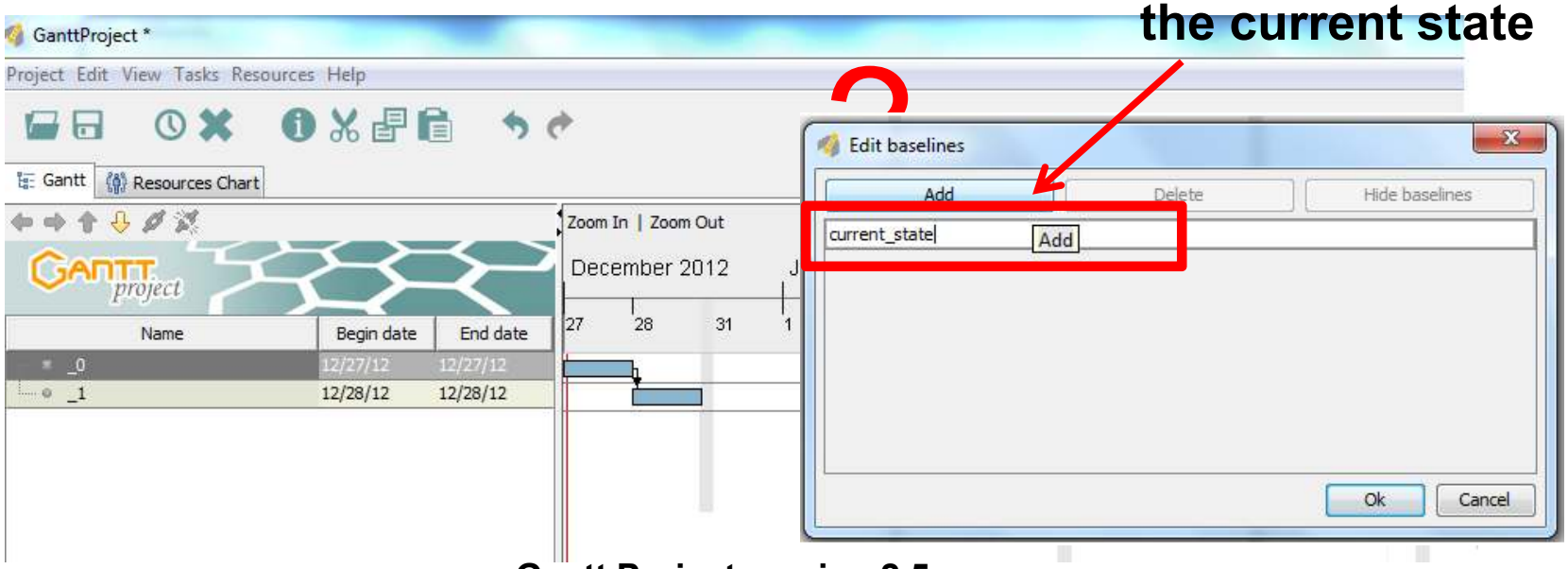
An example repair

Save current state



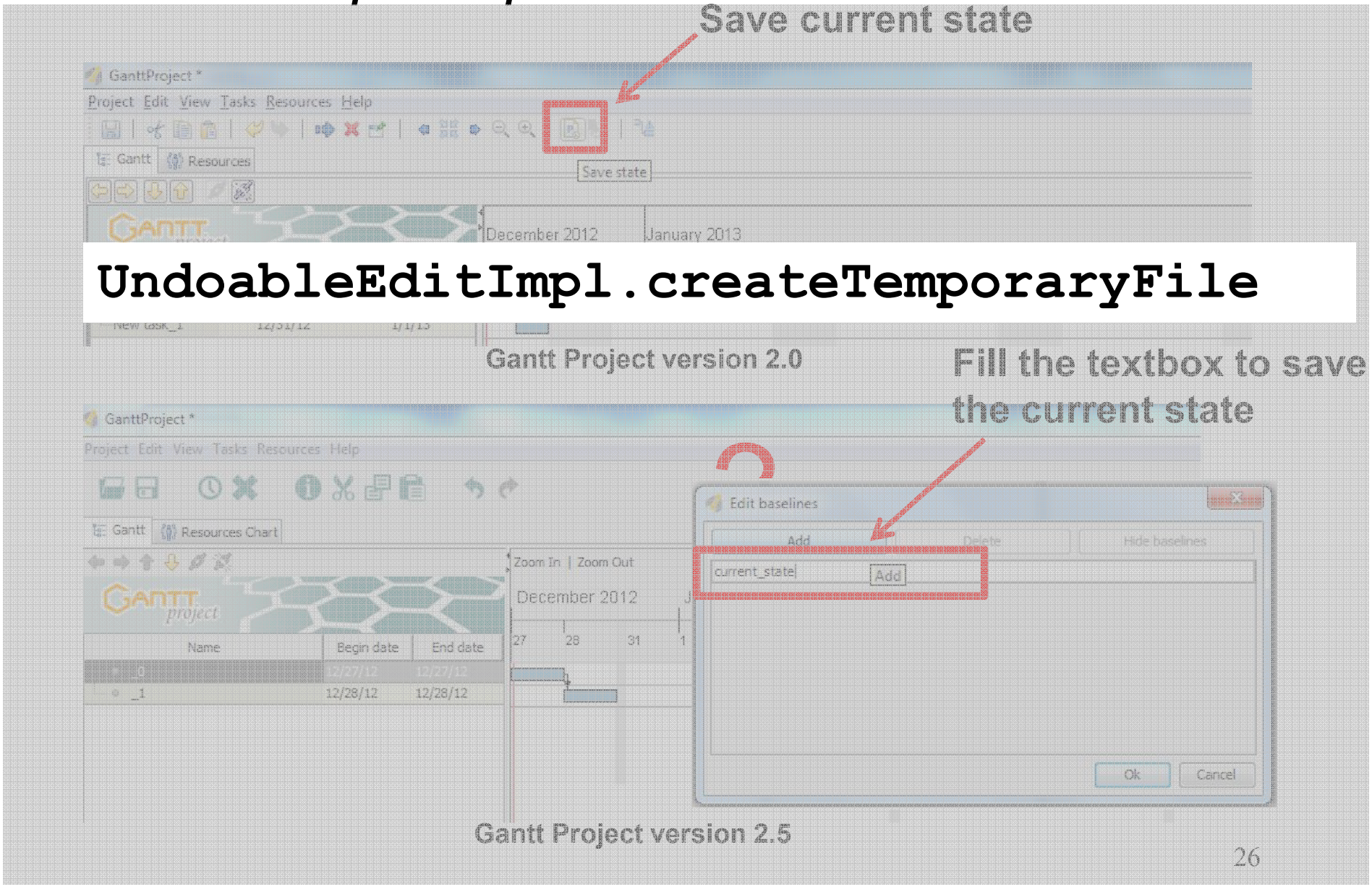
Gantt Project version 2.0

Fill the textbox to save the current state



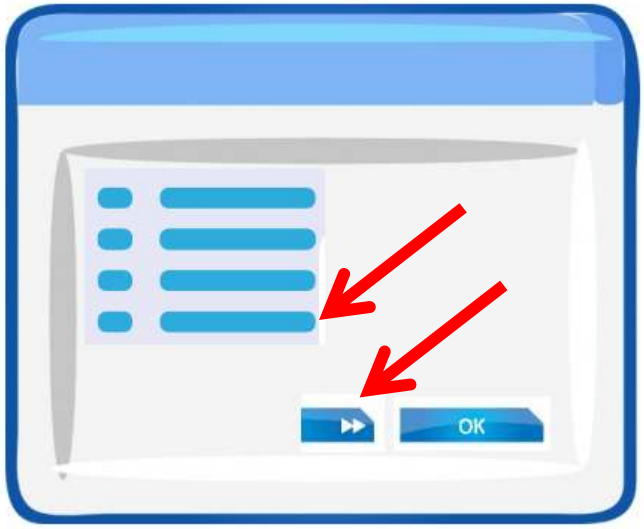
Gantt Project version 2.5

An example repair



Comparison with an existing technique

- **REST**: a GUI-comparison-based technique [Grechanik'09]
  - A black-box approach
  - Compare GUIs of two versions to identify modified UI elements
  - Identifies **affected** actions, but gives **no** repair suggestion



Old version

New version

Comparison with an existing technique

- **REST**: a GUI-comparison-based technique [Grechanik'09]
  - A black-box approach
  - Compare GUIs of two versions to identify modified UI elements
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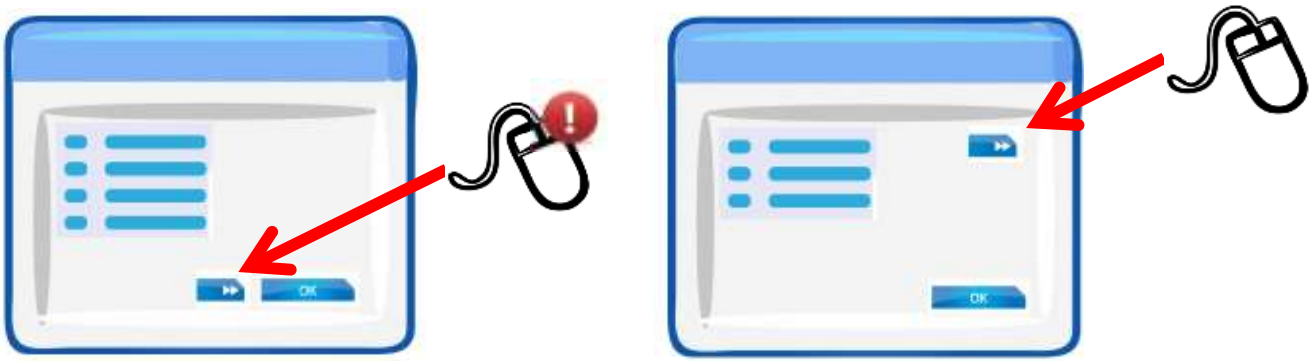
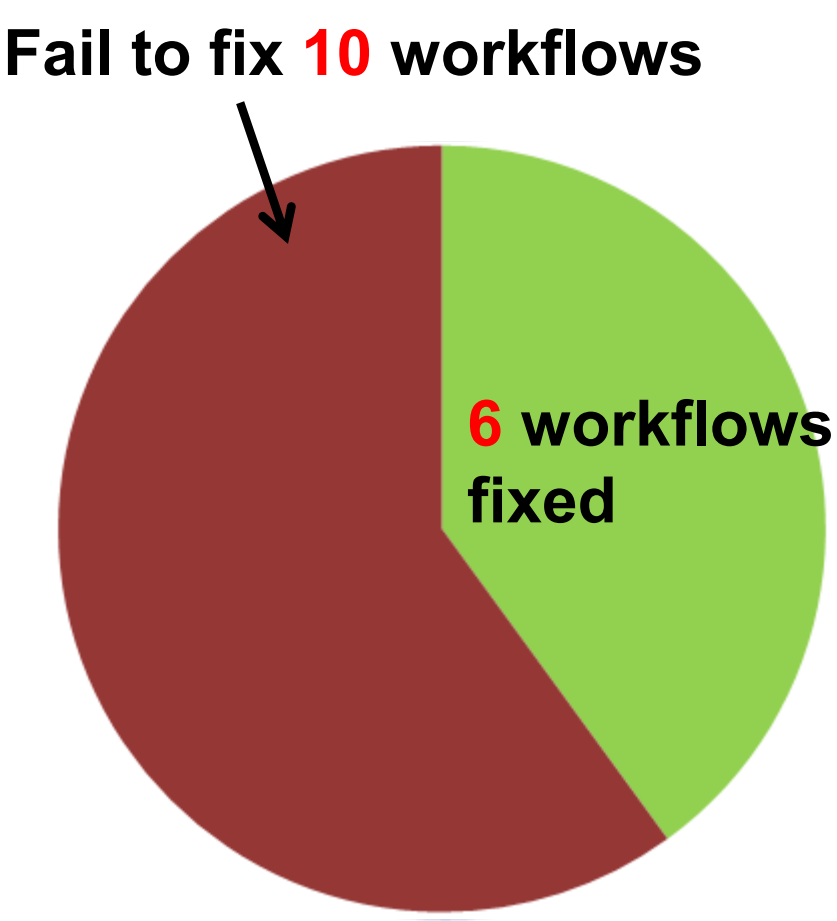
- Extend **REST** for workflow repair
  - Recommend actions on the matched UI element of the new version



REST vs. FlowFixer

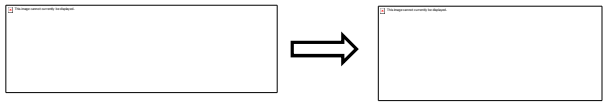


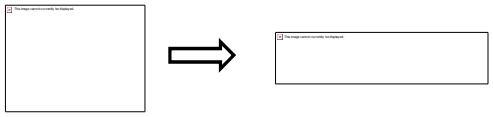
REST

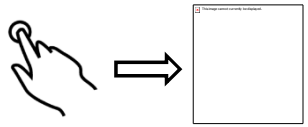
FlowFixer

Why REST did not work well?

- **REST** only repairs 6 workflows where a UI element is *moved* to a different location
  - Ineffective for non-trivial UI changes

UI label change 

UI element change 

UI action change 

- **FlowFixer** repairs 15 broken workflows
  - Execute UI actions and observe their consequences

REST's black-box approach is not aware of the "action semantics"

Experimental conclusions

- FlowFixer is accurate and efficient in repairing broken workflows

- FlowFixer achieves better results than a GUI-comparison-based technique

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Related work

- **Test repair**

  ReAssert [Daniel'09], REST [Grechanik'09], Guitar [Memon'04], Genetic approach [Huang'10], WATER [Choudhary'11] …

  Make obsoleted tests compilable without preserving its original semantics.
  ***Not** applicable to repairing broken workflows.*

- **Program repair**

  GenProg [Weimer'09], ClearView [Perkins'09], PAR [Kim'13]…

  Search patches for bugs.
  ***Not** applicable to broken workflows caused by UI changes.*

- **Change analysis**

  Chianti [Ren'05], SemDiff [Dagenais'08], RefactoringCrawler [Dig'05], Hybrid approach [Wang'12] …

  Identify code-level changes and compute the effects.
  ***Not** applicable for repairing UI-level workflows.*

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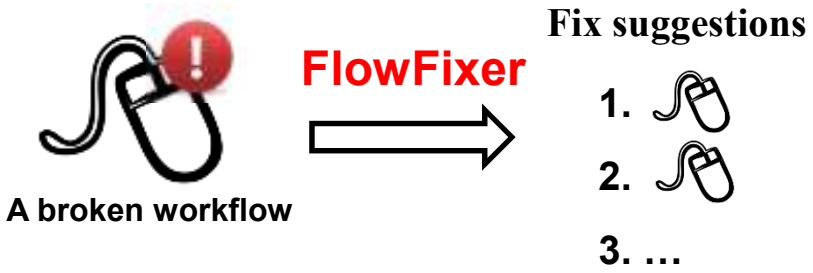
Future directions

- User study
- Extend FlowFixer to repair UI test scripts
  - Lift *syntax-correcting* repair to *semantics-preserving* repair
- Integrate FlowFixer into software evolution
  - Proactively finding broken workflows
  - Summarize UI-level changes
  - Automatically update user manual
  - Help users learn new GUI features

Contributions



- A technique to repair broken workflows

  analyze method invocations and evolution to reason about fix actions

  – fully automated

  – handles non-trivial code changes

- Experiments that demonstrate its usefulness

  – Accurate and efficient

    - Fixed 15 out of 16 broken workflows

  – Outperforms alternative techniques

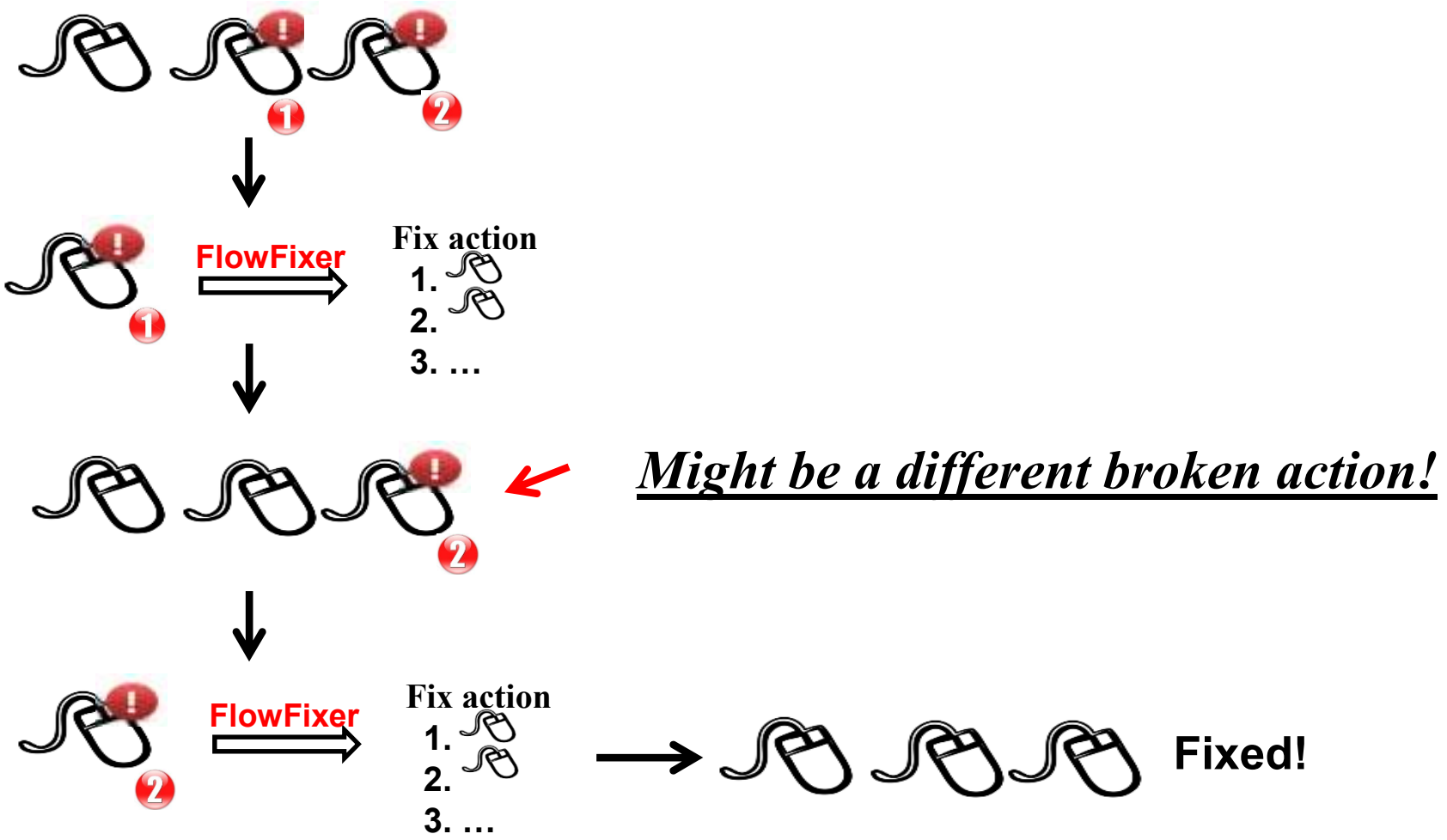
- The FlowFixer tool implementation:

  http://workflow-repairer.googlecode.com

[Backup Slides]

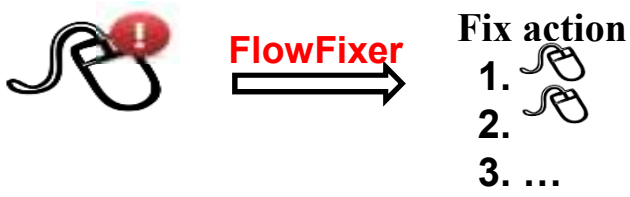
What if multiple actions are broken?

- Use FlowFixer in an interactive way

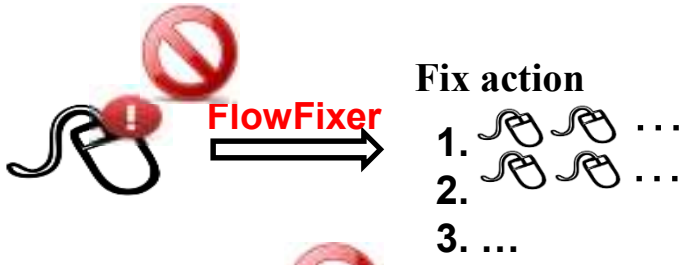


FlowFixer's recommendation limitation

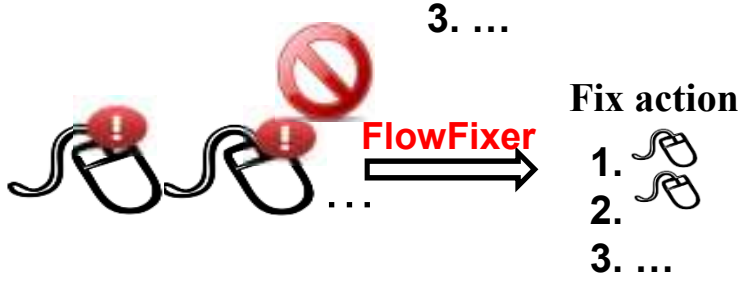
- Recommends one replacement action for a broken action



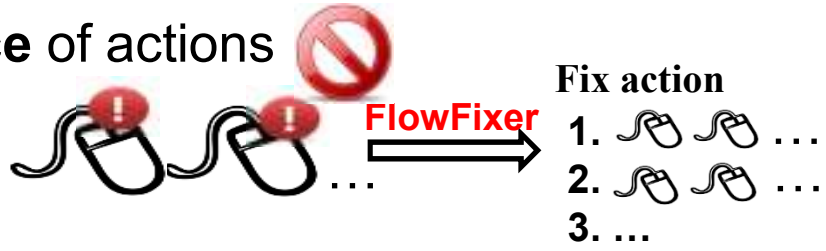
- Does not support recommending:
  - A **sequence** of actions for **one** action



  - **One** action for a **sequence** of actions

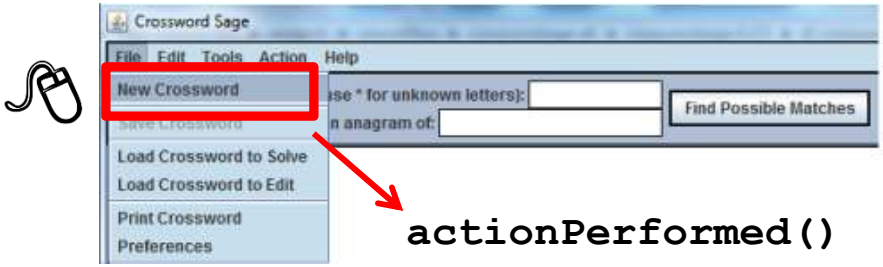


  - A **sequence** of actions for a **sequence** of actions



Why does this simple random testing work?

- Goal:
  - Identify **"signature" method** for each UI action
  - NOT achieve good coverage
- The "signature" method is often easy to reach:



- Symbolic, model-based techniques might achieve better results, but are more expensive to use