Automatically Repairing Broken Workflows for Evolving GUI Applications

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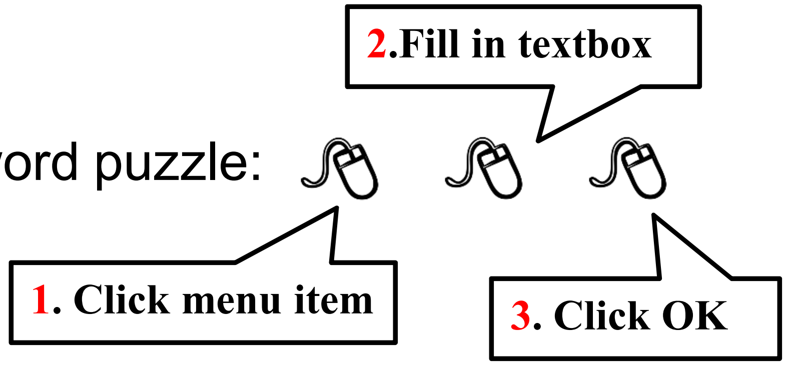
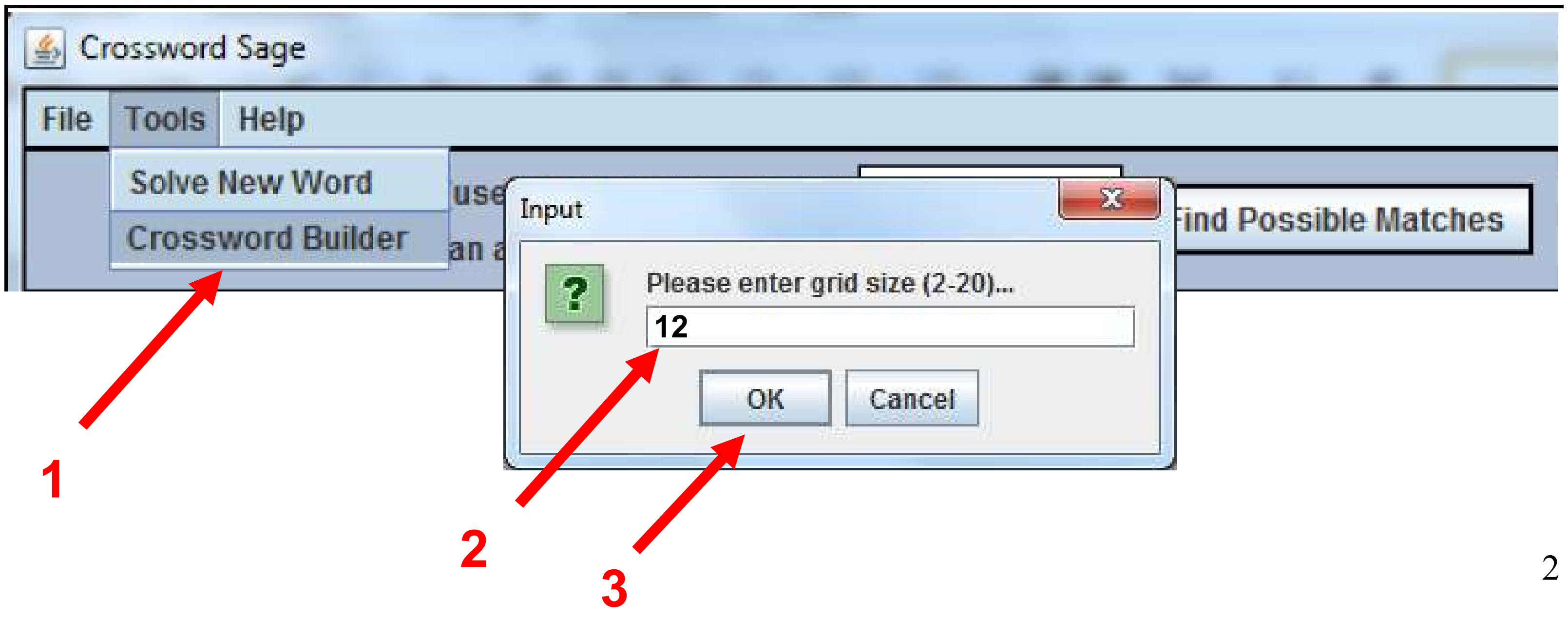
End-user's workflow

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

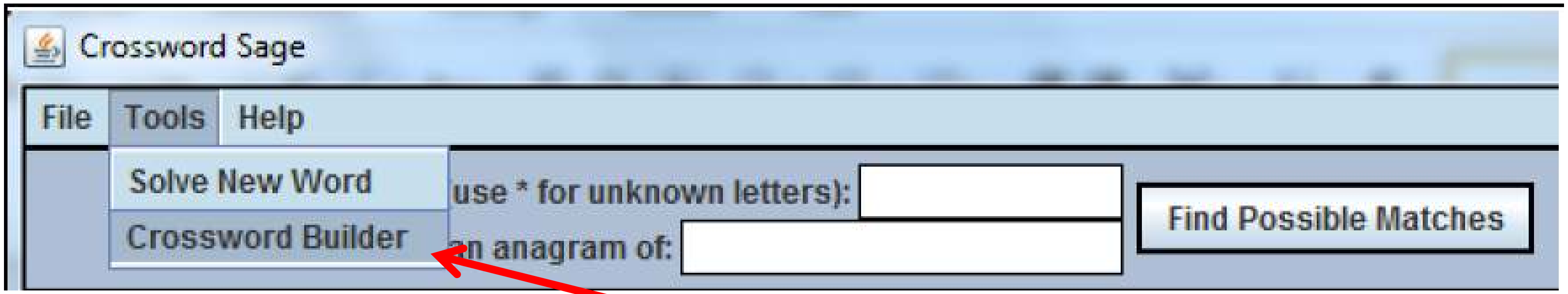
Example:

A 3-action workflow of creating a crossword puzzle:



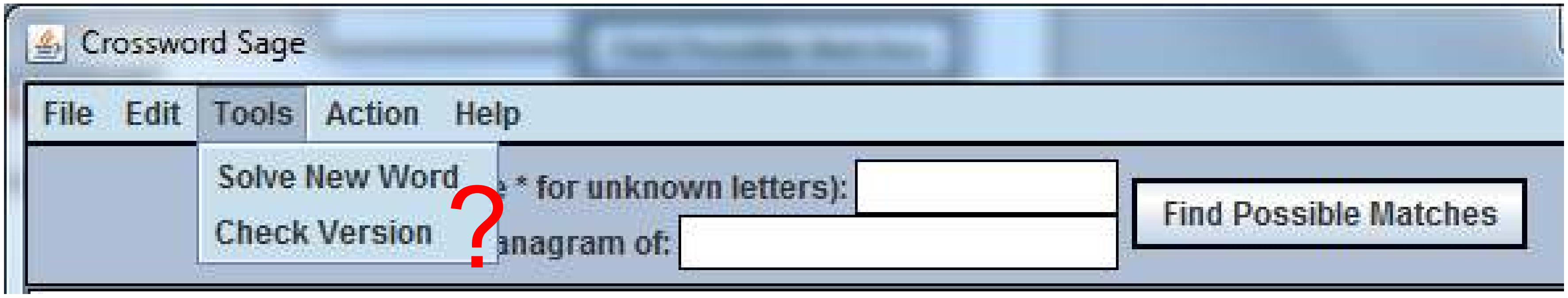


GUI evolution can break workflows



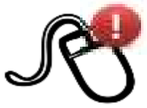
Version 0.3

(the first action in creating a puzzle)



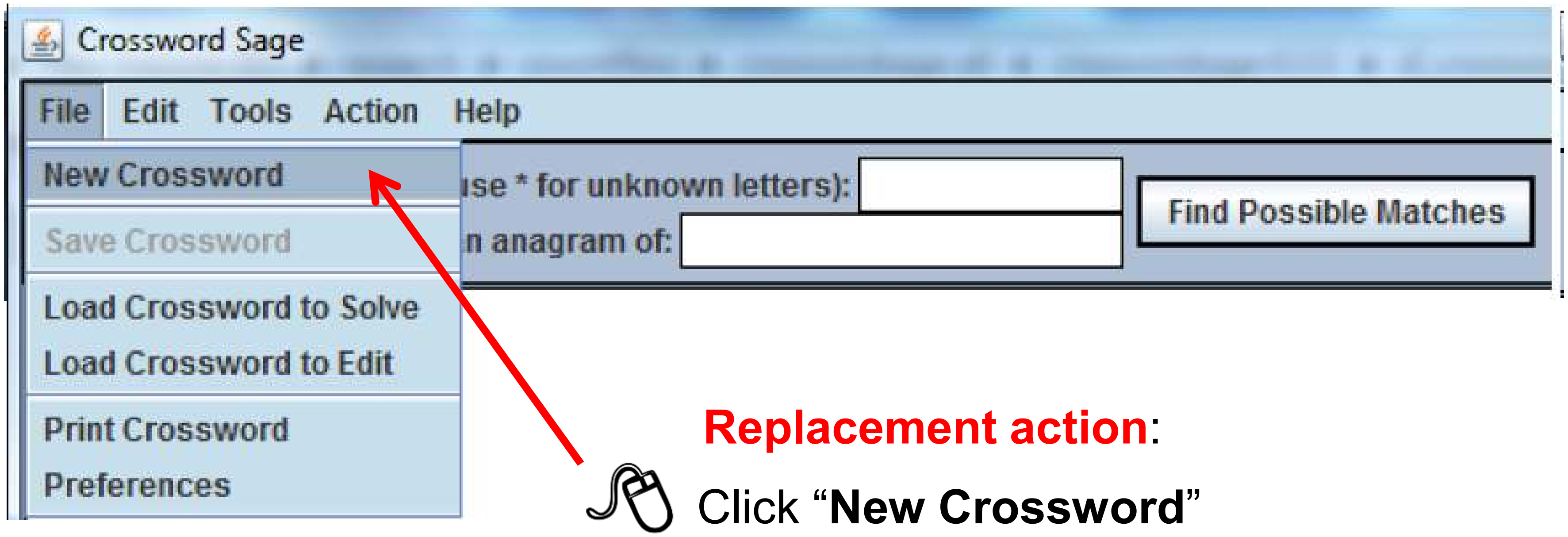
Version 0.35

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

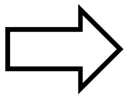


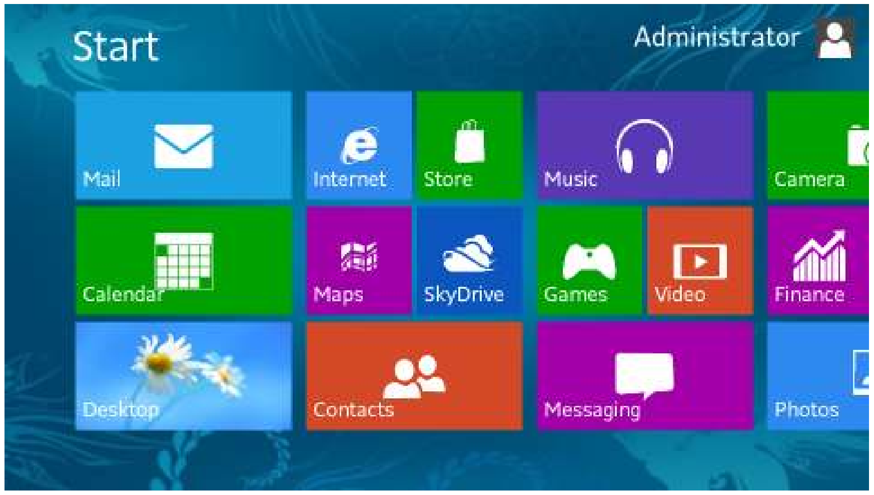
Replacement action:

Click "**New Crossword**"

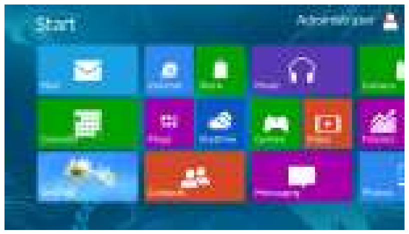
(Suggested by our technique: **FlowFixer,** since both invoke method "**`showCrosswordBuilder`**")

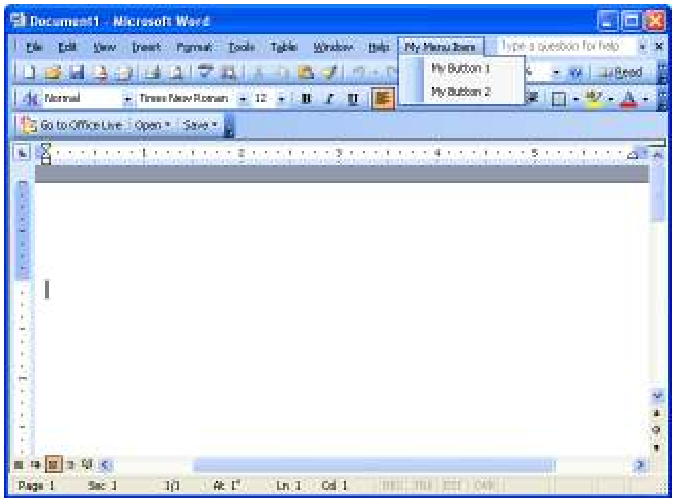
GUIs keep evolving all the time

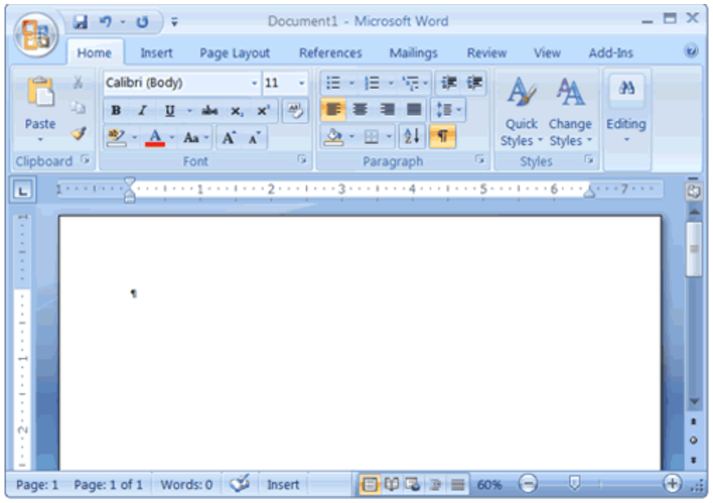




GUIs keep evolving all the time







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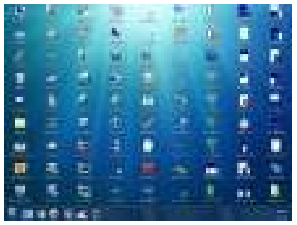

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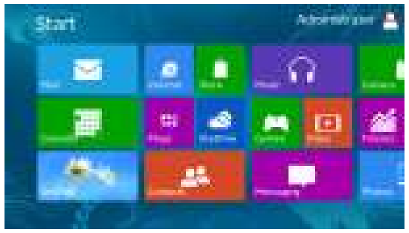

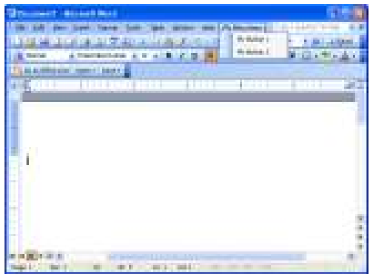

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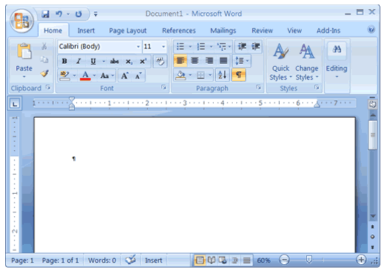

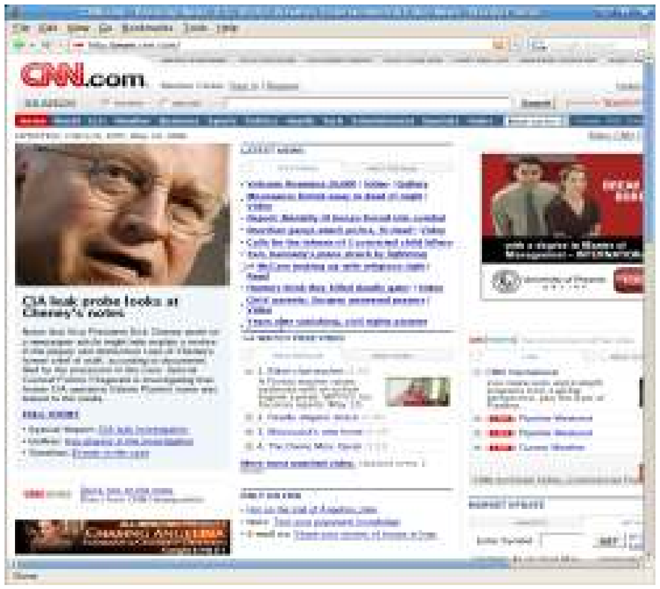

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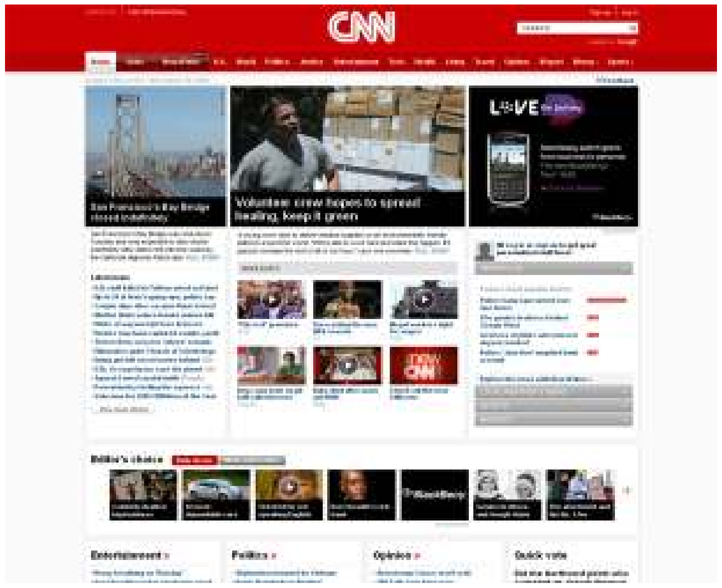

GUIs keep evolving all the time

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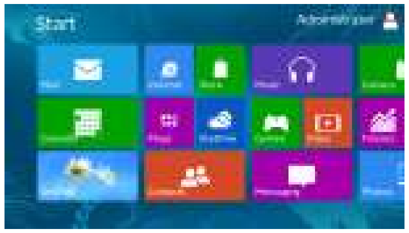

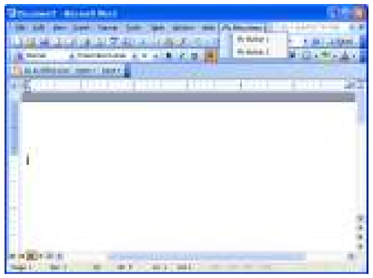

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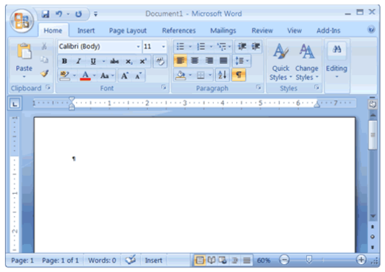

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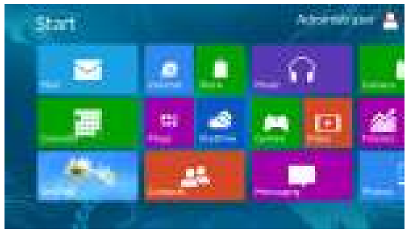
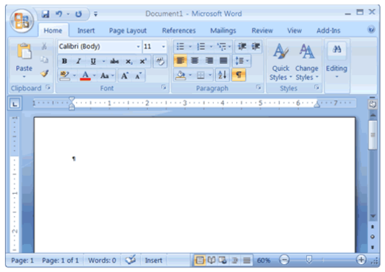
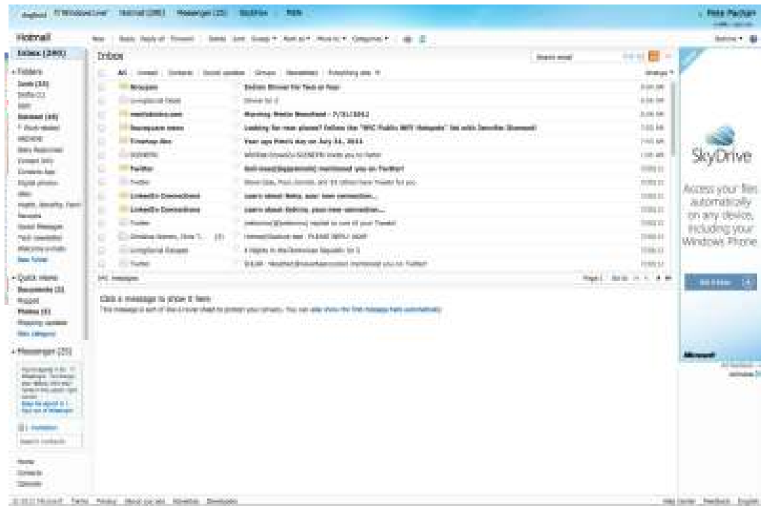
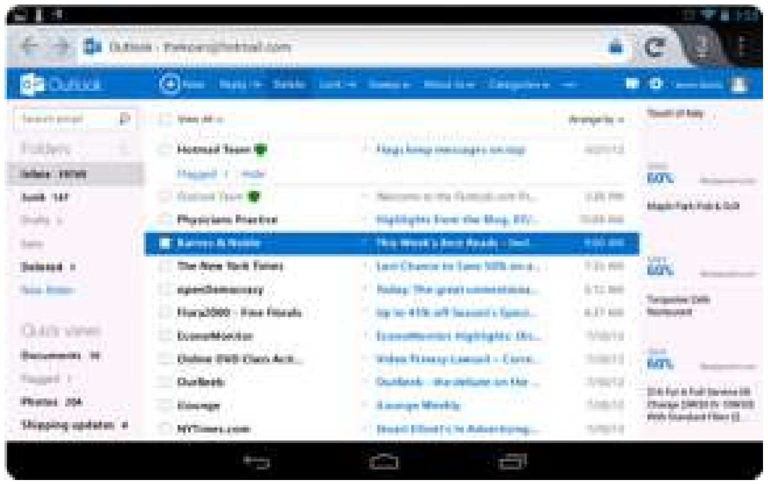
GUIs keep evolving all the time









GUIs keep evolving all the time

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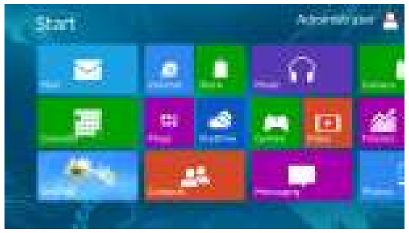

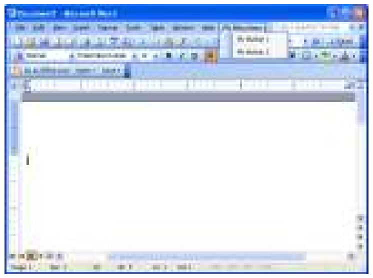

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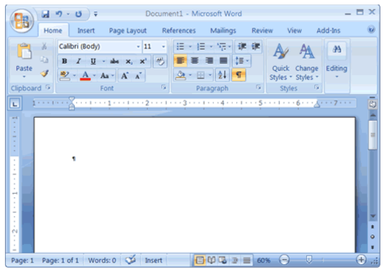

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⇒

GUI evolution can break workflows!

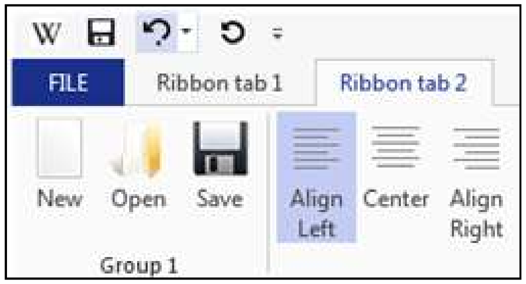
Broken workflows in practice

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

Microsoft Office Community

100+ posts

Example: the ribbon UI in Office 2007



- **Impact automated testing**

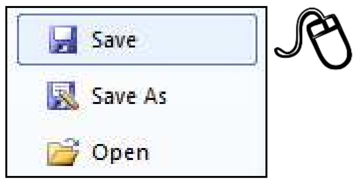
UI Test script

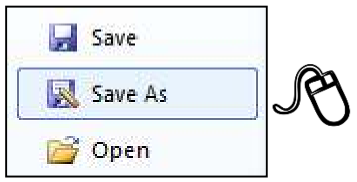
- mimic workflows
- **30 – 70%** of them are broken in GUI evolution [Memon'03, Grechanik'09, Daniel'11]

Tedious and challenging to resolve them manually

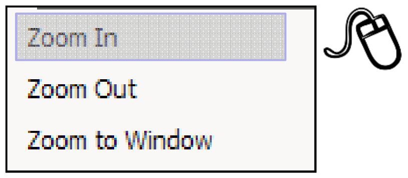
The "action semantics" challenge

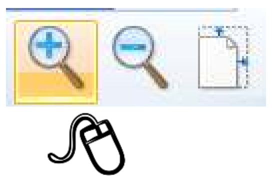
- A UI action's effect cannot be observed statically
- Repairing broken workflows needs to:
  - distinguish actions that *look similar* but have *different results*





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





Requires knowing the "what the action does"

Outline

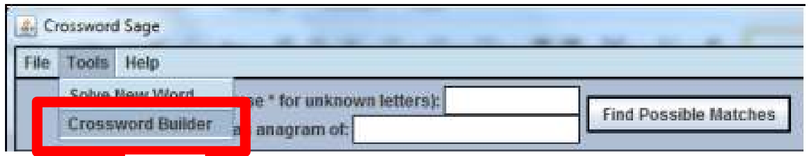
- Problem
- ➡ Technique
- Evaluation
- Related Work
- Contributions

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

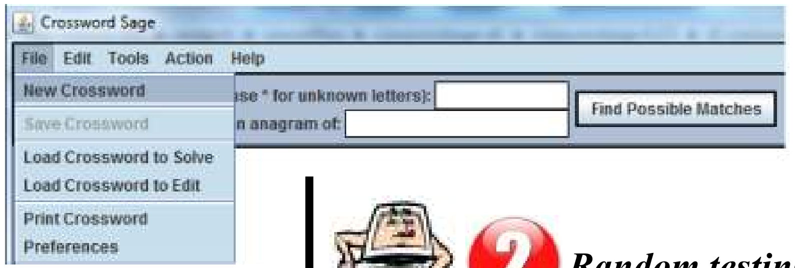
An overview of the FlowFixer technique

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()
...
```

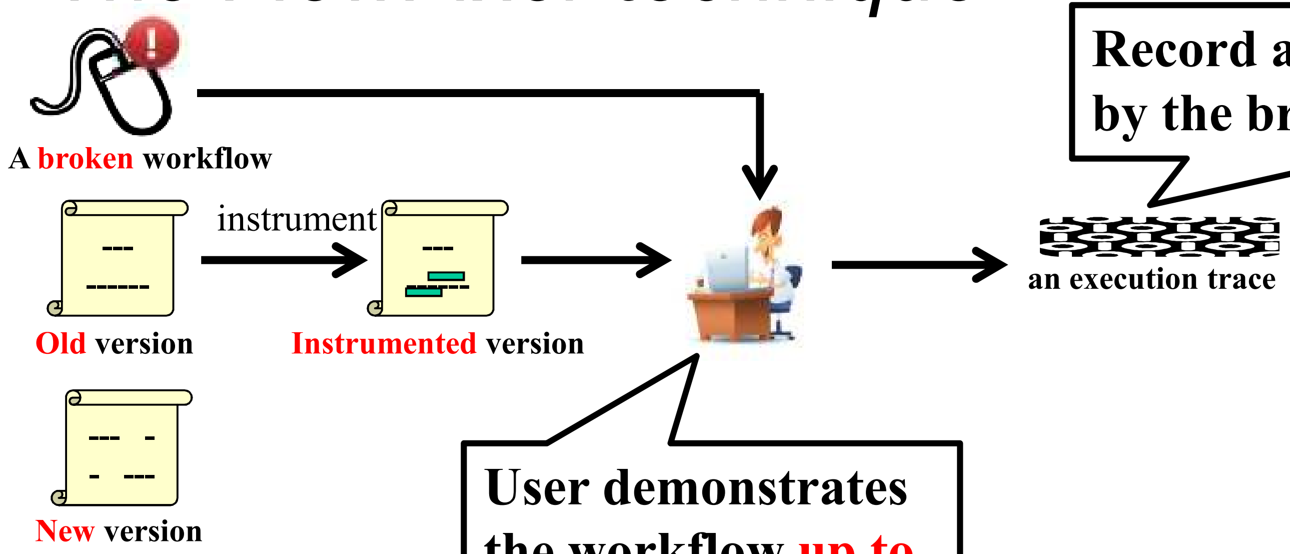
3. Click “Solve New Crossword” 1/3

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

4 **Replacement actions:**

1. Click “New Crossword”
2. …

The FlowFixer technique

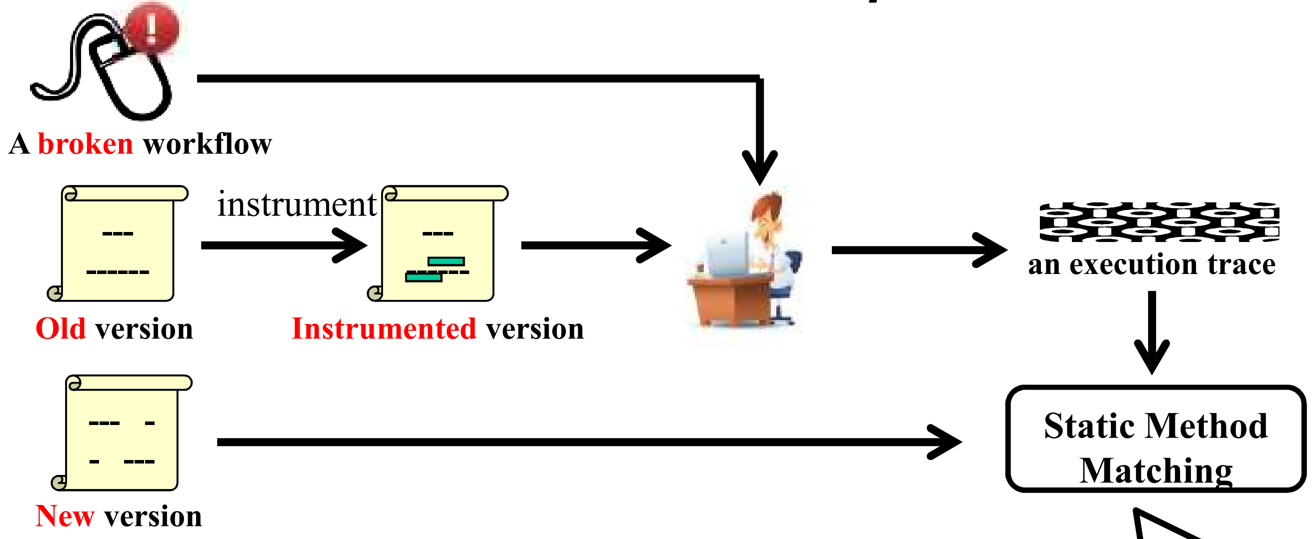


Record all methods invoked by the broken action

User demonstrates the workflow up to the broken action

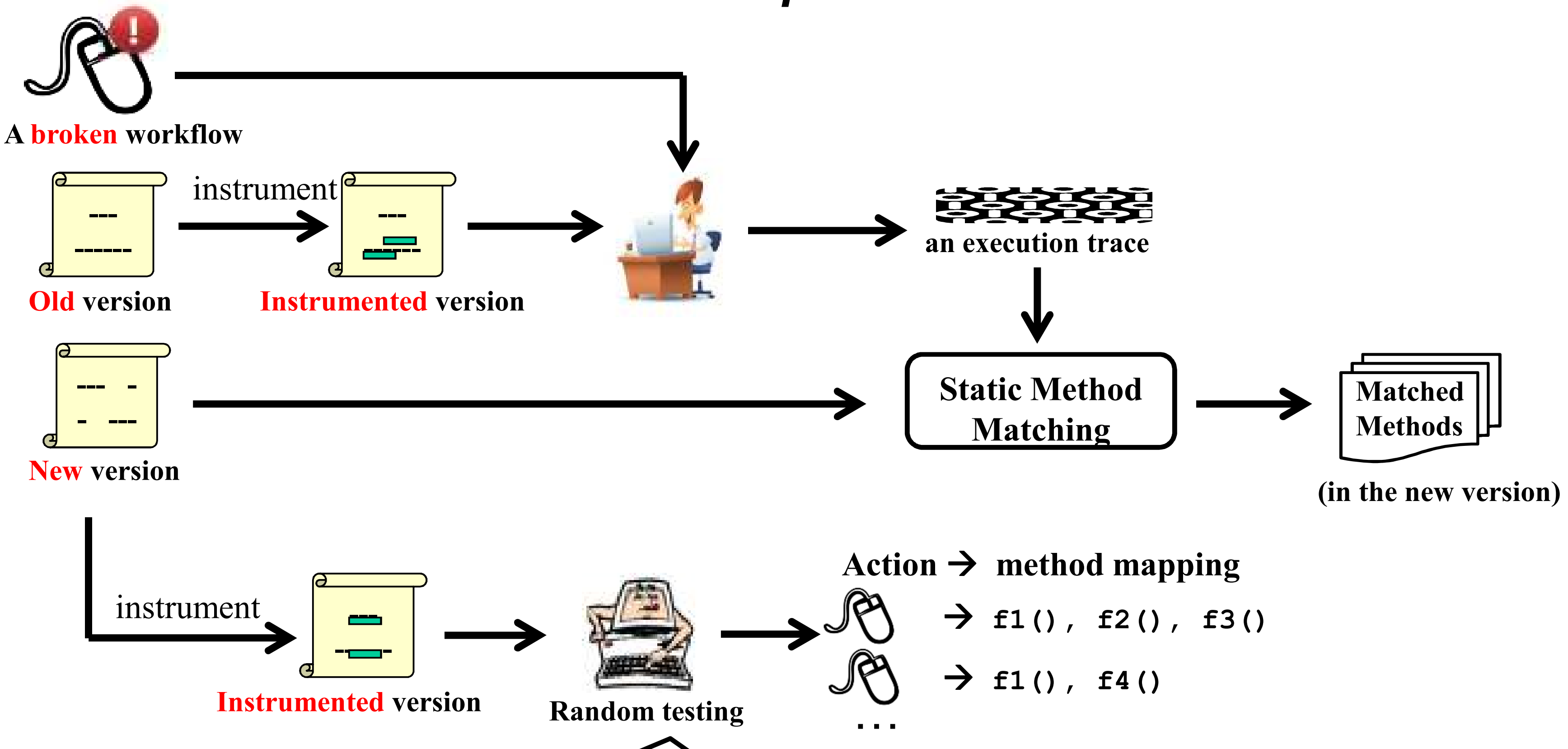
(the first action is broken)

The FlowFixer technique



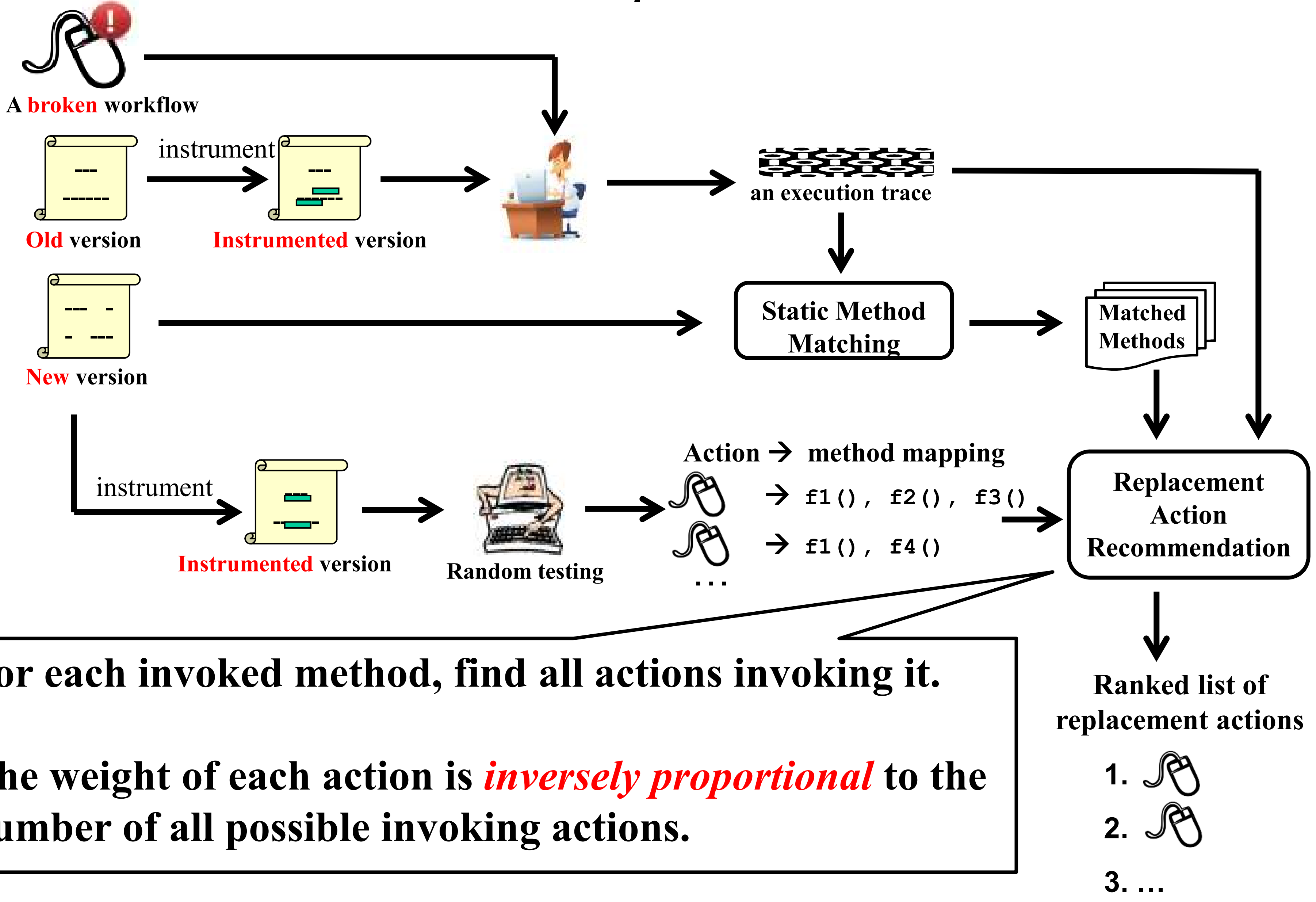
Match each method invoked by the broken action in the new version

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

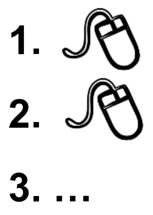
Non-trivial code changes

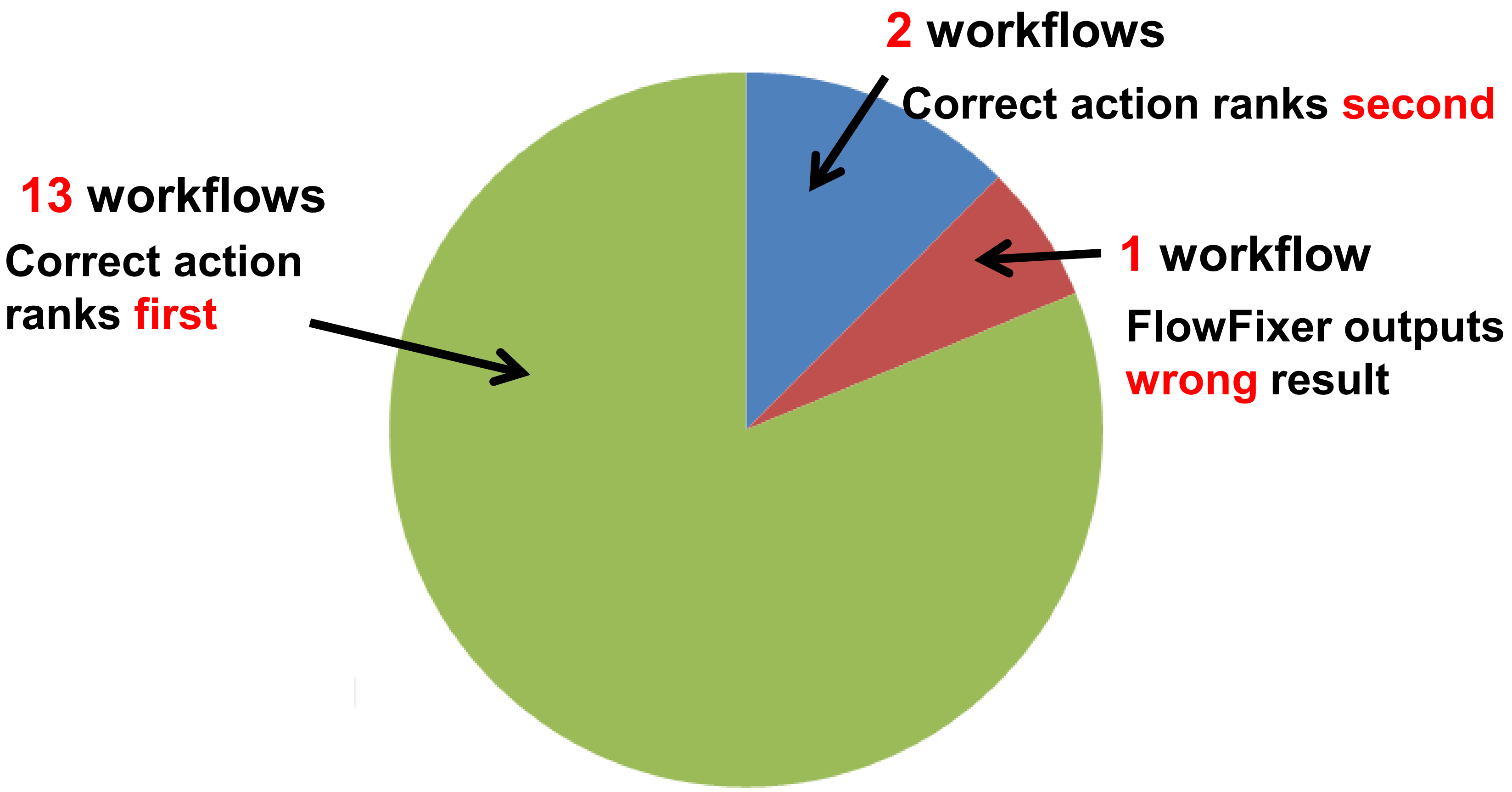
16 workflows with distinct root causes. Collected from user manual.

- 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





FlowFixer can repair 15 broken workflows

FlowFixer's efficiency

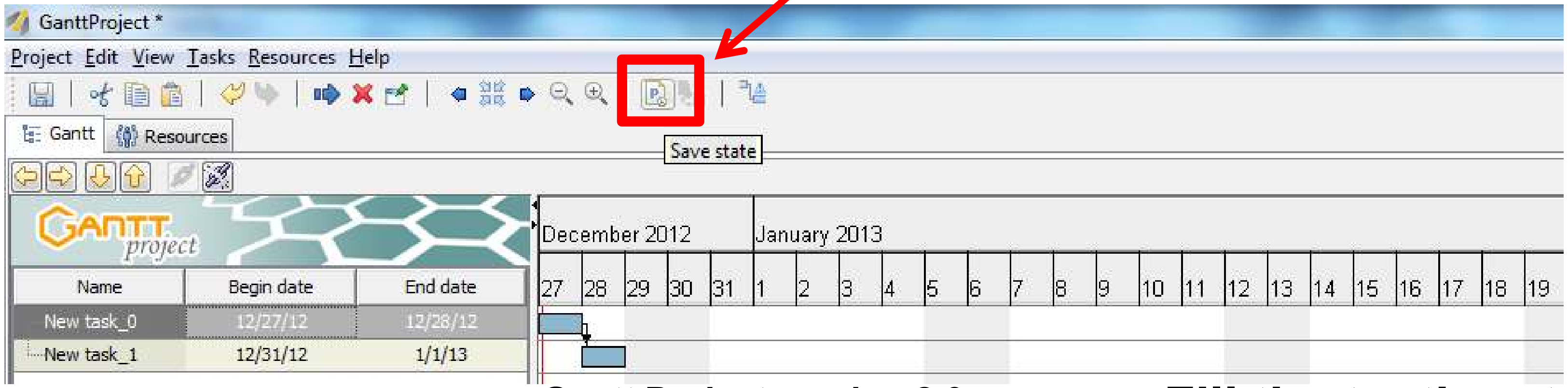
- **Random testing**
  - 27 mins per *application*
    (*A **one-time** cost, shared by different workflows*)

- **User demonstration**
  - **<** 1 min per workflow
    (assuming the old version is installed)

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

An example repair

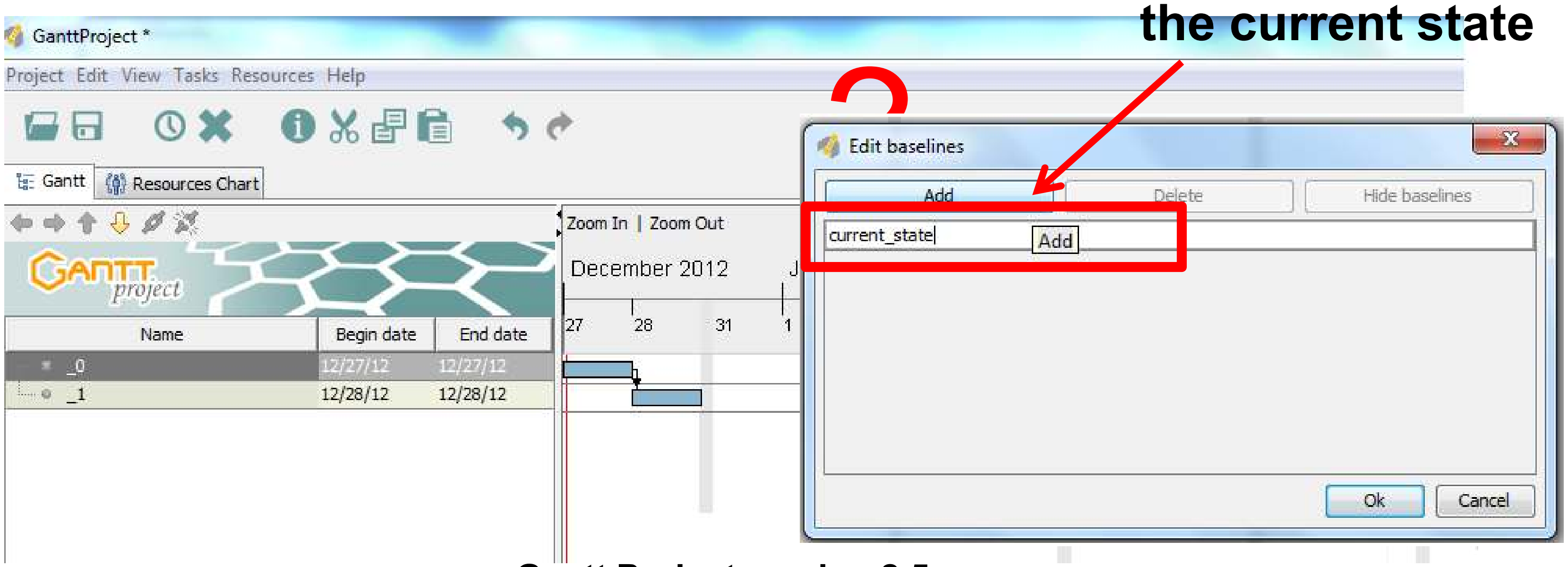
Save current state



Name	Begin date	End date
New task_0	12/27/12	12/28/12
New task_1	12/31/12	1/1/13

Gantt Project version 2.0

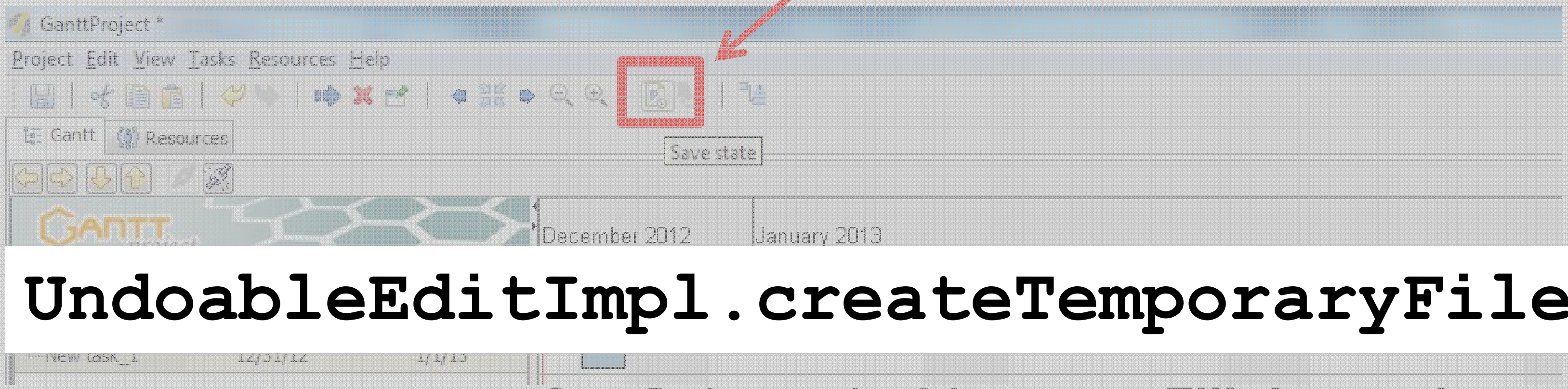
Fill the textbox to save the current state



Name	Begin date	End date
_0	12/27/12	12/27/12
_1	12/28/12	12/28/12

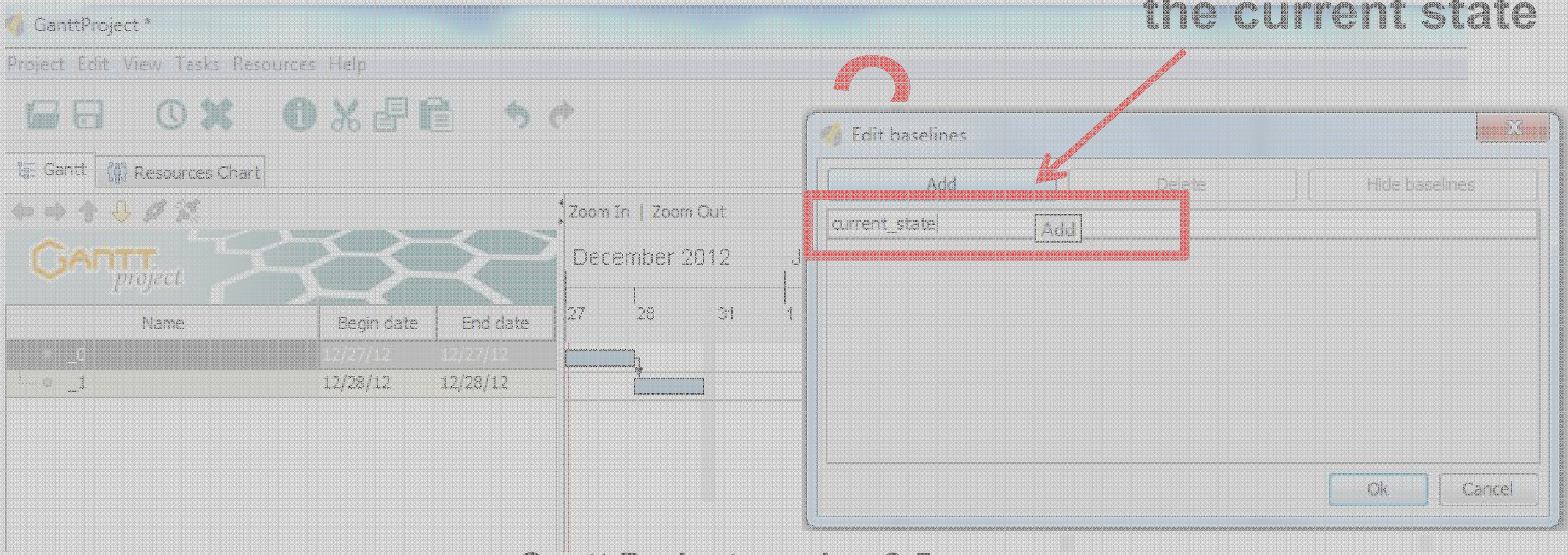
Gantt Project version 2.5

An example repair



UndoableEditImpl.createTemporaryFile

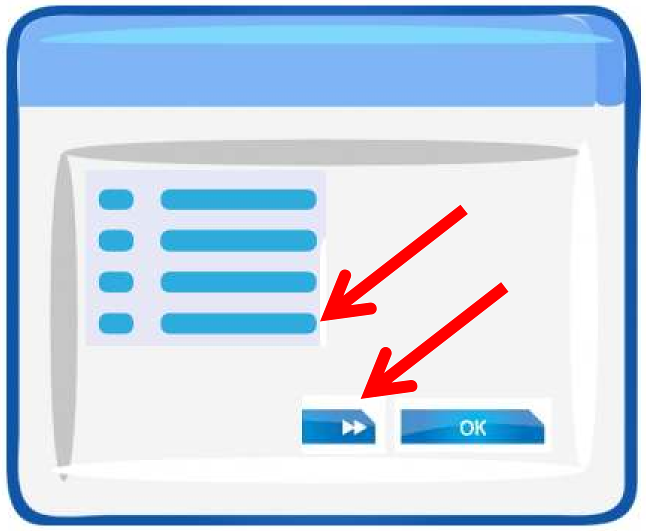
Gantt Project version 2.0



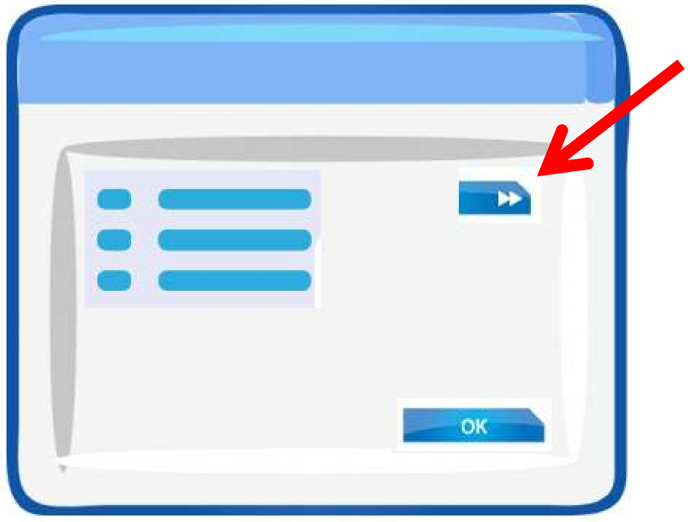
Gantt Project version 2.5

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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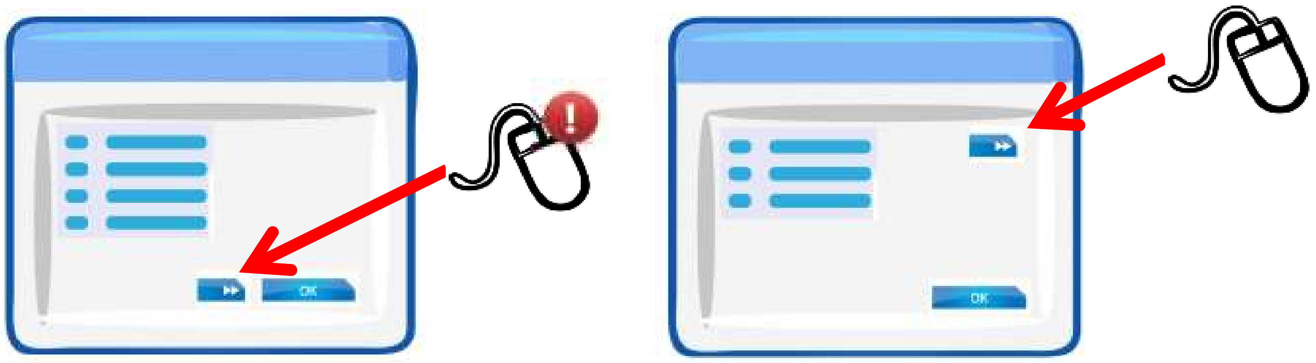
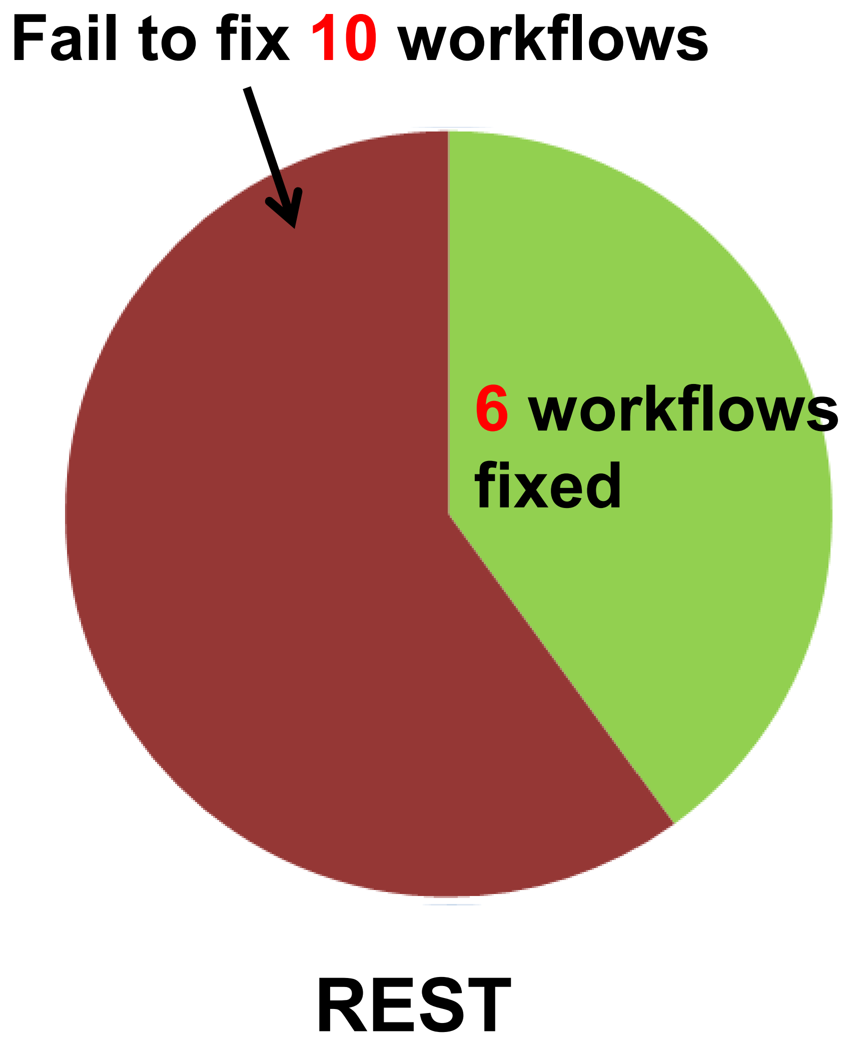
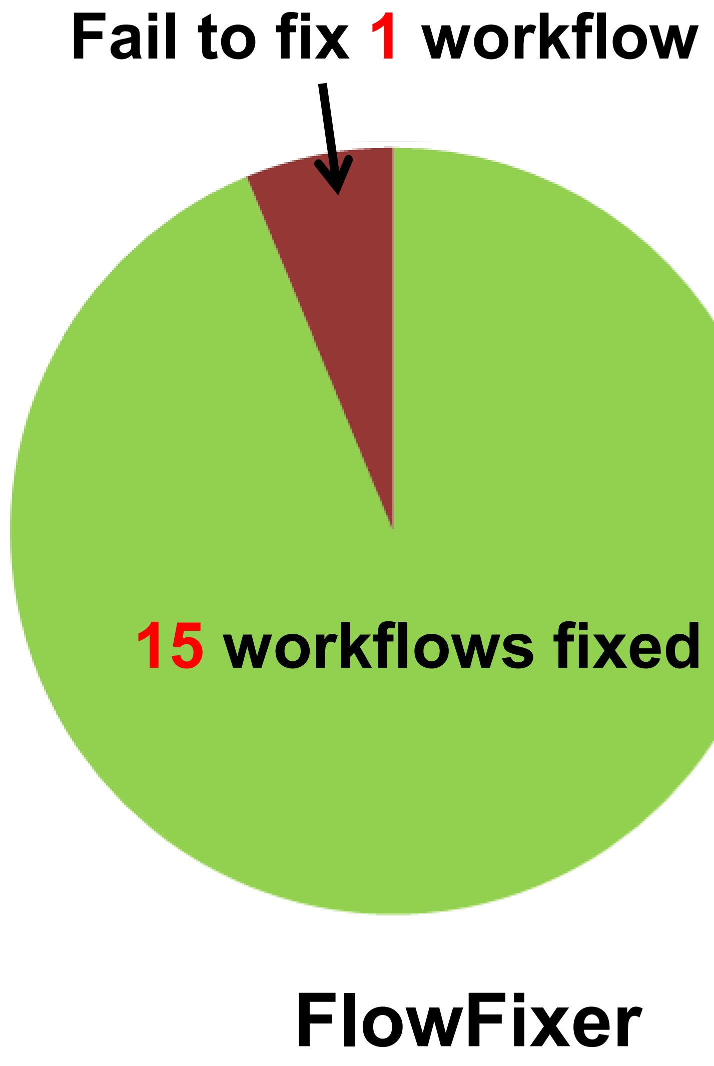
- Extend **REST** for workflow repair
  - Recommend actions on the matched UI element of the new version



Old version **New version**

REST vs. FlowFixer

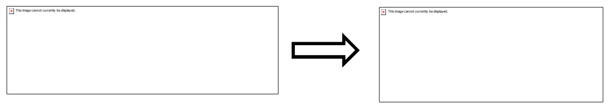




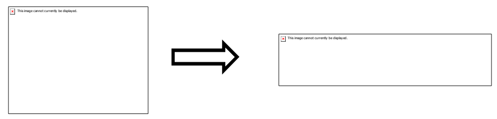
Why REST did not work well?

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

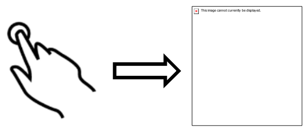
    UI label change



    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

Outline

- Problem
- Technique
- Evaluation
- ➡ Related Work
- Contributions

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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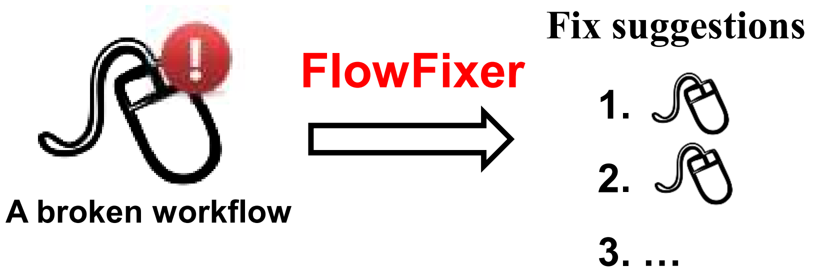
Future directions

- 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

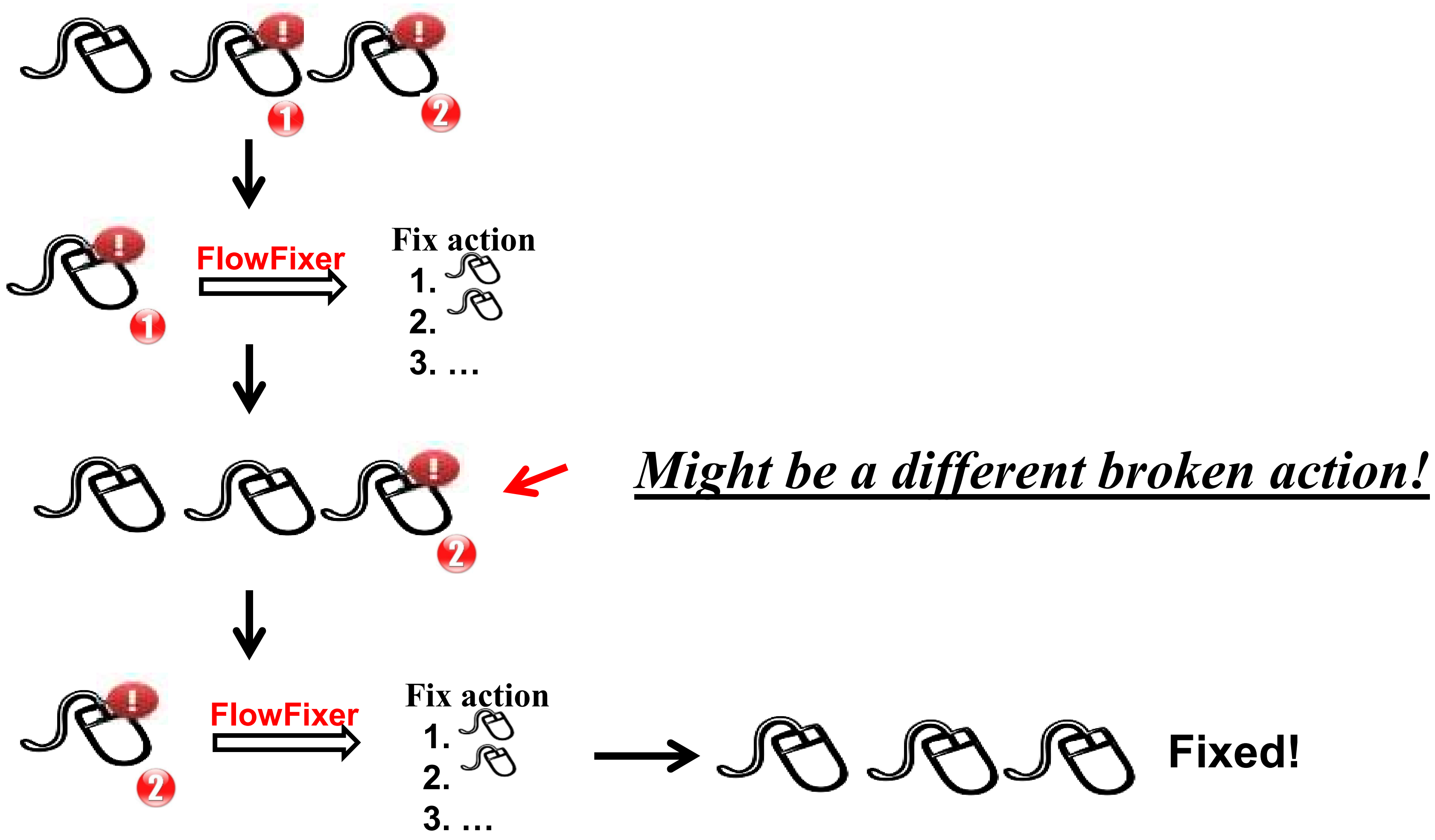
- The FlowFixer tool implementation:

  http://workflow-repairer.googlecode.com

[Backup Slides]

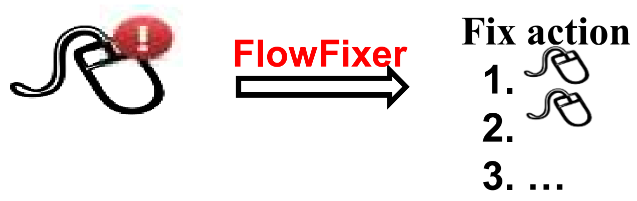
What if multiple actions are broken?

- Use FlowFixer in an interactive way

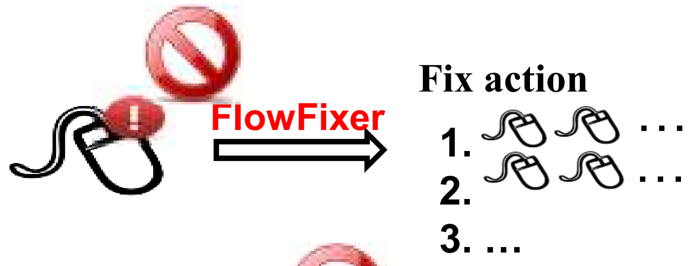


FlowFixer's recommendation limitation

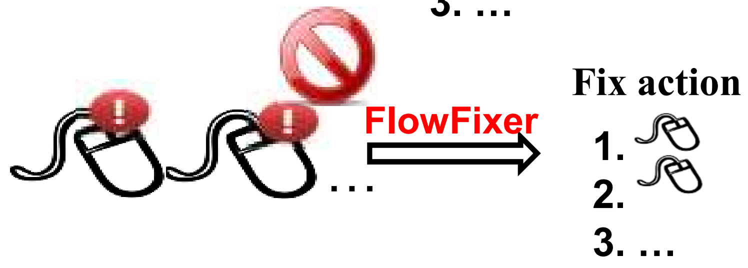
- Recommends one replacement action for a broken action



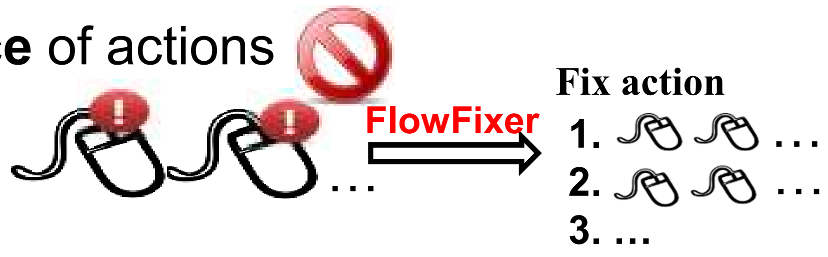
- Does not support recommending:
  - A **sequence** of actions for **one** action



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



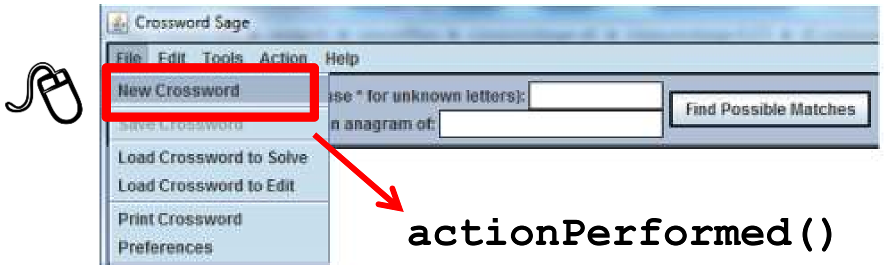
  - A **sequence** of actions for a **sequence** of actions



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:



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

Event handler, shared by many actions

A “**signature**” method, only invoked by “Clicking New Crossword”

Other methods. Requires certain states

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