AppFlow: Using Machine Learning to Synthesize Robust, Reusable UI Tests

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Background

- UI Testing is very challenging
  - Largely relies on scripting
  - High initial development cost
  - “Testing bugs”
- “application UIs are designed for human intelligence but test scripts are low level click-by-click scripts”
- Test re-use is difficult
  - Despite flow similarity-- designs are always different so recognition is difficult
  - Even similar apps in the same category have different flows
Introducing … AppFlow

- “AppFlow provides ‘smoke tests’ or build verification testing for each source code change, requiring little or no manual work”
- Learns a classifier from a training dataset of screens and widgets labeled with their intents
  - texts, widget sizes, image recognition results of graphical icons, optical character recognition (OCR)
- Training dataset comes from a developer community for an app category
  - AppFlow provides utilities to simplify data collection
  - Map variant screens and widgets to canonical ones.
    - “Your Email” or “example@email.com” on sign-in screens to signin.username
AppFlow research at a higher level

- **Initial Benefits**
  - UI can be updated without rewriting unit tests
  - Multiple screen sizes supported without re-writing tests

- **Flow-based testing**
  - Pre-condition
  - Post-condition
  - User steps

- **Android-based**
- **Tested on widely used apps**
An example test

Scenario: add to shopping cart [stay at cart]
   Given screen is detail
   And cart_filled is false
   When click @addtocart
   And click @cart
   And not see @empty_cart_msg
   Then screen is cart
   And set cart_filled to true

Figure 1: Flow: “add to shopping cart”.
An example test

**pre-condition**

*Scenario:* add to shopping cart [stay at cart]

- Given screen is detail
- And cart_filled is false

**user steps**

- When click @addtocart
- And click @cart

**post-condition**

- And not see @empty_cart_msg
- Then screen is cart
- And set cart_filled to true

**Figure 1:** Flow: “add to shopping cart”.
An example test

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   Given screen is detail
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User-defined “abstract property”

Figure 1: Flow: “add to shopping cart”.
“Abstract properties are intended to keep track of the invisible portions of app states, which can often be crucial for writing robust tests.”
An example test

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*Figure 1: Flow: “add to shopping cart”.*
AppFlow Workflow

Figure 2: Workflow of AppFlow. The stick figure here represents developer intervention.
AppFlow Workflow

Phase 1
mostly one-time, prepares AppFlow for testing a new category of apps

Figure 2: Workflow of AppFlow. The stick figure here represents developer intervention.
AppFlow Workflow

Phase 2 applies AppFlow to test each new app in the category

Figure 2: Workflow of APPFLOW. The stick figure here represents developer intervention.
Phase 1: Preparing a new category

1. Create a test library in AppFlow that contains common flows for category
2. Define canonical screens and widgets
3. Use AppFlow utilities to capture and label a dataset of screens and widgets
4. Add samples from other app categories*
5. AppFlow extracts key features from each sample and learns classifiers to recognize screens and widgets based on them

*Sometimes apps in different categories share similar screens
Phase 2: Adding a new app

1. Customize library for app
   a. Use AppFlow GUI to detect and fix errors in UI detection
   b. Add custom test flows to accommodate app

2. Run test cases
   a. AppFlow uses the flows in the test library to synthesize full tests
   b. At first, only the “start app” flow is active, discovers more flows
   c. Process terminates when no more flows need to be tested
UI Recognition

- Feature selection includes description text, size, whether it is clickable; the UI layout of the object; and the graphics.

- **Classifying Screens**
  - Inputs: UI screenshot, code class-naming
  - Output: canonical screen

- **Classifying Widgets (“interactables”)**
  - Inputs: Widget text, widget context, widget metadata, neighbour information, OCR, graphical features
  - Output: canonical widget or “not a widget”
AppFlow GUI
Writing flows

- Follows ‘Gherkin’s syntax’ (Behavior-Driven Development)
  - “Unlike in Gherkin which use natural languages for the conditions and step, AppFlow uses visible and abstract properties”
  - Pre-condition → Given
  - Steps → When
  - Post-condition → Then

- Verbs are common operations and checks, such as “see”, “click”, and “text”

- Widgets can be canonical (assigned) ones or real (defined in library)
  - Canonical ones are referenced with @<canonical widget name>
Examples

Scenario: perform user login
  Given screen is signin
  And loggedin is false
  When text @username '@email'
  And text @password '@password'
  And click @login
  Then screen is not signin
  And set loggedin to true

Scenario: enter shopping cart [signed in]
  Given screen is main
  And loggedin is true
  When click @cart
  Then screen is cart
AppFlow Best Practices

1. Flows should be modular for re-use
2. Test-flows should only refer to canonical screens and widgets
   a. Avoids string checking-- if you are looking for a screen refer to that screen
3. Reduce rare flows in library
   a. Avoids test-debugging for future developers
4. Keep flows simple
   a. More properties increases test-time
   b. (User-centered!)
Results

- Six main metrics for evaluation centered around usability and impact
- For 40 and 20 top apps in shopping and news respectively
  - 55.2%, 53% (test re-use)
  - 90.2%, 81.5% (screen detection)
  - 88.7%, 85.9% (widget detection)
  - 5.7, 4.5 (# of average flow lines)
- JackThreads
  - 46.6% of the test cases can be created automatically

Figure 4: Number of apps each flow can test. The x-axis shows the flows, and the y-axis show the number of apps.
Discussion

- AppFlow market impact
- AppFlow for prototyping and building
- Your thoughts???