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

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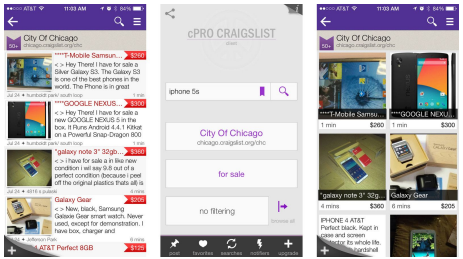
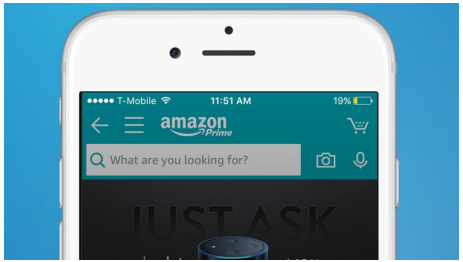
Background

- 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

user steps

post-condition

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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.”

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User-defined
“abstract property”

Figure 1: Flow: “add to shopping cart”.

An example test

User defined action

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```

"Add to Cart" Button

Figure 1: Flow: "add to shopping cart".

AppFlow Workflow

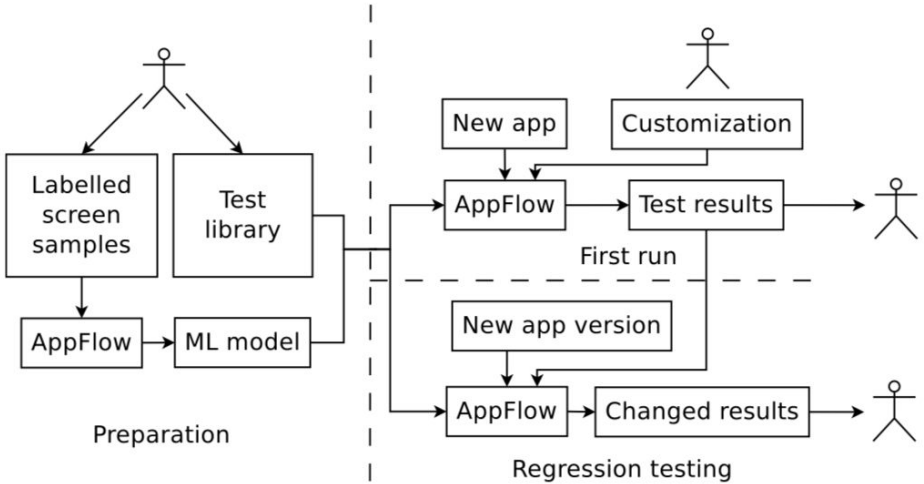
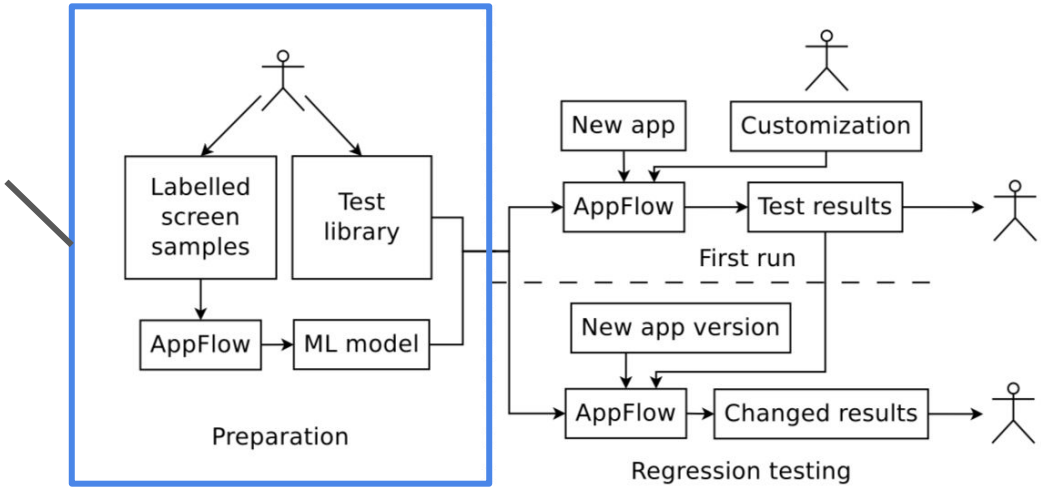


Figure 2: Workflow of AppFlow. The stick figure here represents developer intervention.

AppFlow Workflow

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



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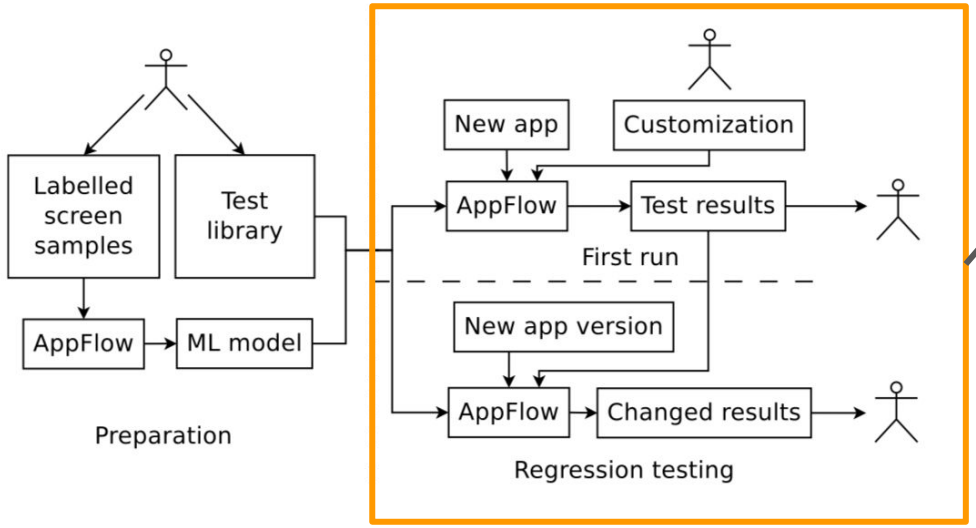
AppFlow Workflow



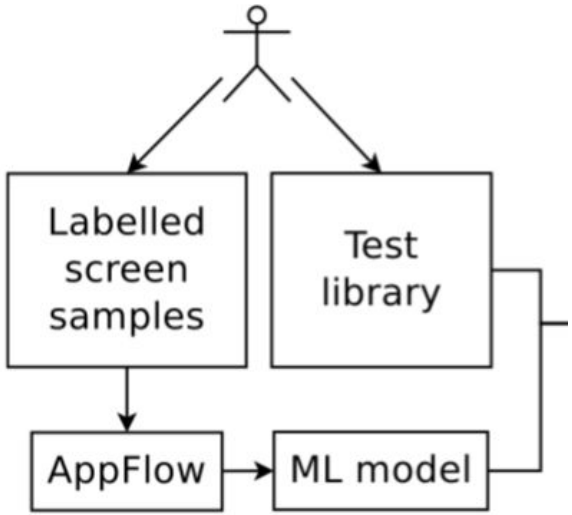
Phase 2
applies AppFlow to test each **new app** in the category

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

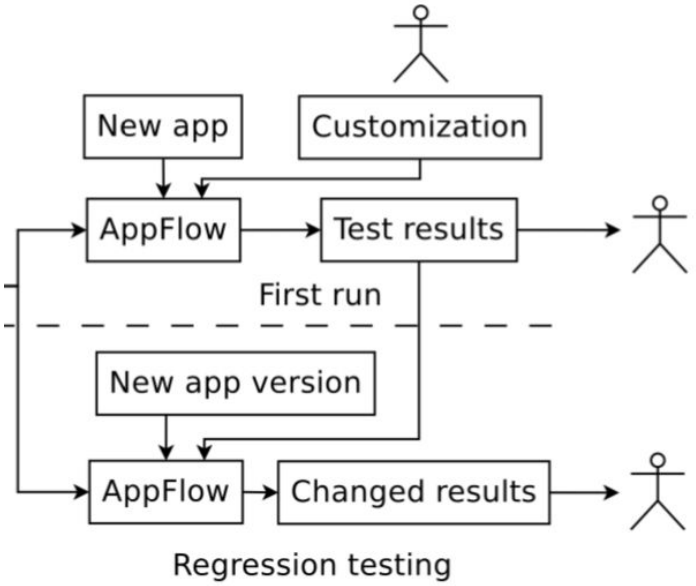
*Sometimes apps in different categories share similar screens



Preparation

Phase 2: Adding a new app

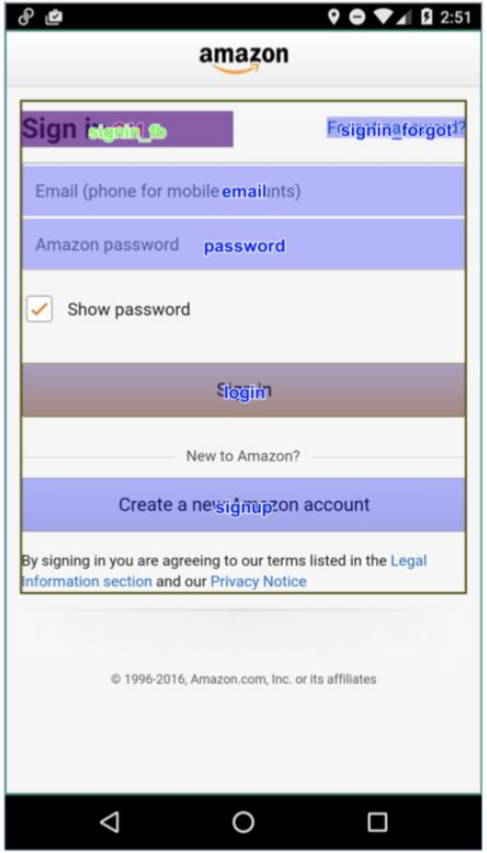
1. Customize library for app
   a. Use AppFlow GUI to detect and fix errors in UI detection
   b. Add custom test flows to accommodate app
2. Run test cases
   a. AppFlow uses the flows in the test library to synthesize full tests
   b. At first, only the “start app” flow is active, discovers more flows
   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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amazon
Sign in
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Email (phone for mobile emailints)
Amazon password
password
Show password
login
New to Amazon?
Create a new Amazon account
signup
By signing in you are agreeing to our terms listed in the Legal Information section and our Privacy Notice
© 1996-2016, Amazon.com, Inc. or its affiliates


Please enter label
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Label:
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cart_count
email
password
login
share
placeorder
signin
signup
cat
menu
back
cart
search
continue
Cancel
OK

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

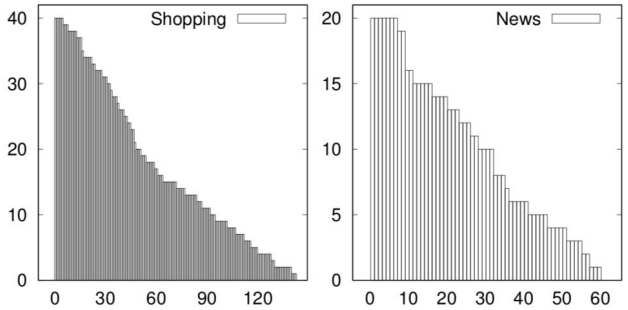

Figure 4: Number of apps each flow can test. The x-axis shows the flows, and the y-axis show the number of apps.

Discussion

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