NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

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StoryDroid: Automated Generation of Storyboard for Android Apps

ICSE 2019
Montréal, QC, Canada

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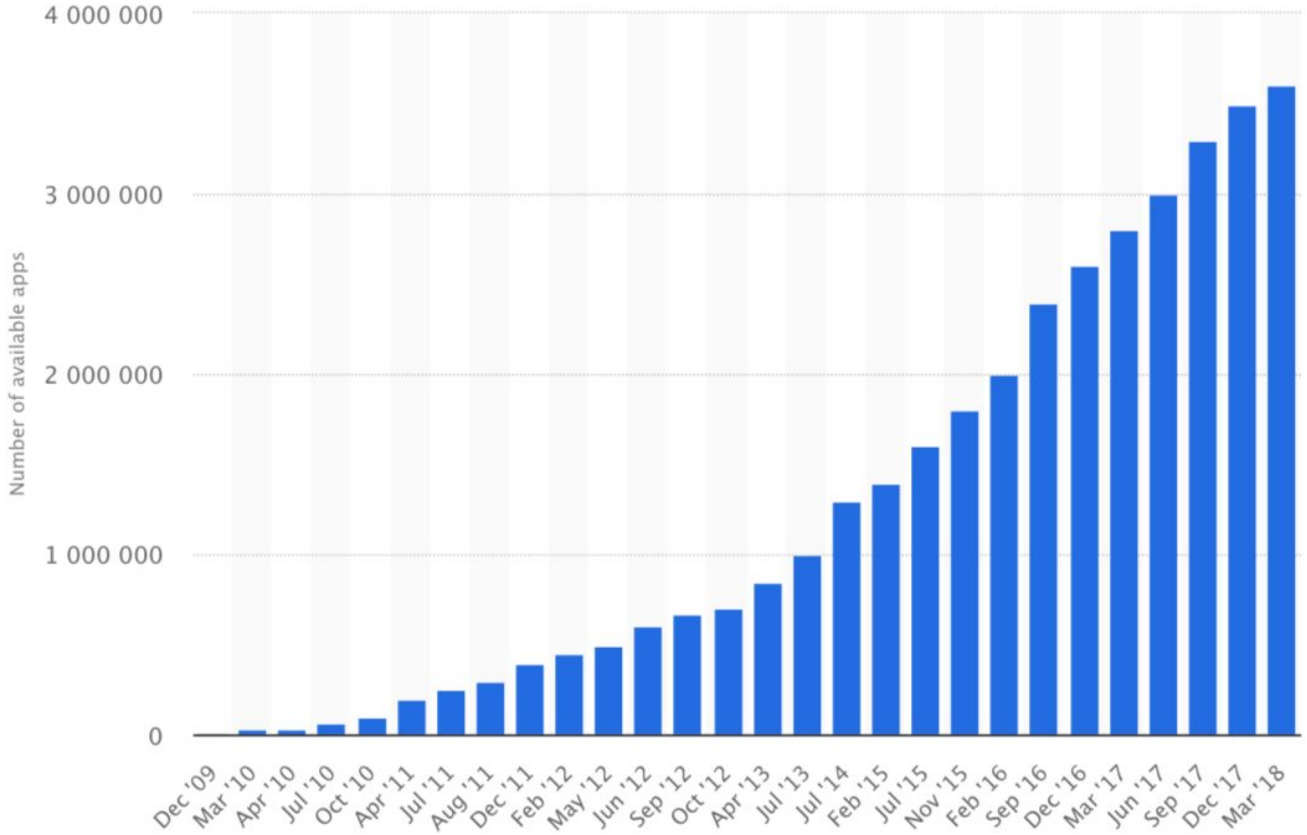
Mobile apps are continuously increasing



One Single App Category

Over 3.8 million Android apps are available at Google Play Store.

One single app category usually contains many similar Android apps.

Searching apps from Google Play Store

Mobile apps are facing fierce competitions.

Before developing a new mobile app

Development team usually endeavors painstaking efforts to review many existing apps (i.e., competitive analysis) with similar purposes.

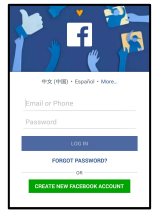
Similar purposes of competitive analysis

- helps understand the competitors' strengths and weaknesses
- helps developers gain more insights on the actual implementation
- reduces market risks before development

Reviewing apps for competitive analysis

Eve: Product Manager → Functionalities

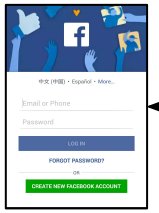
Login



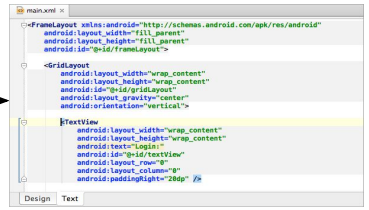
Main

Alice: UX/UI Designer → UI design and layout code

Login



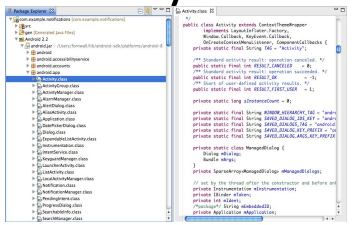
Layout Code



Bob: App Developer → Logic code

Login

Activity Code



However…

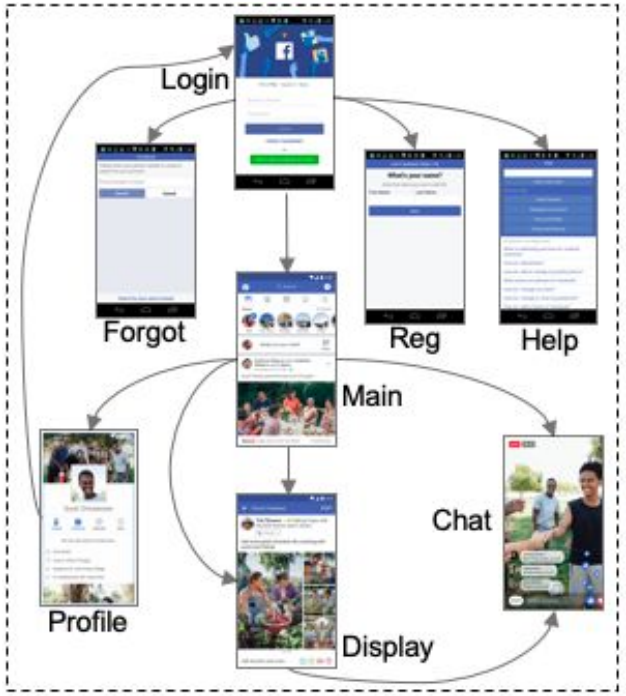
Manual exploration of hundreds of existing similar apps by different roles is ineffective.

- ✔ It is a time-consuming task.
- ✔ it is difficult to explore all the functionalities.

How to improve the reviewing efficiency?

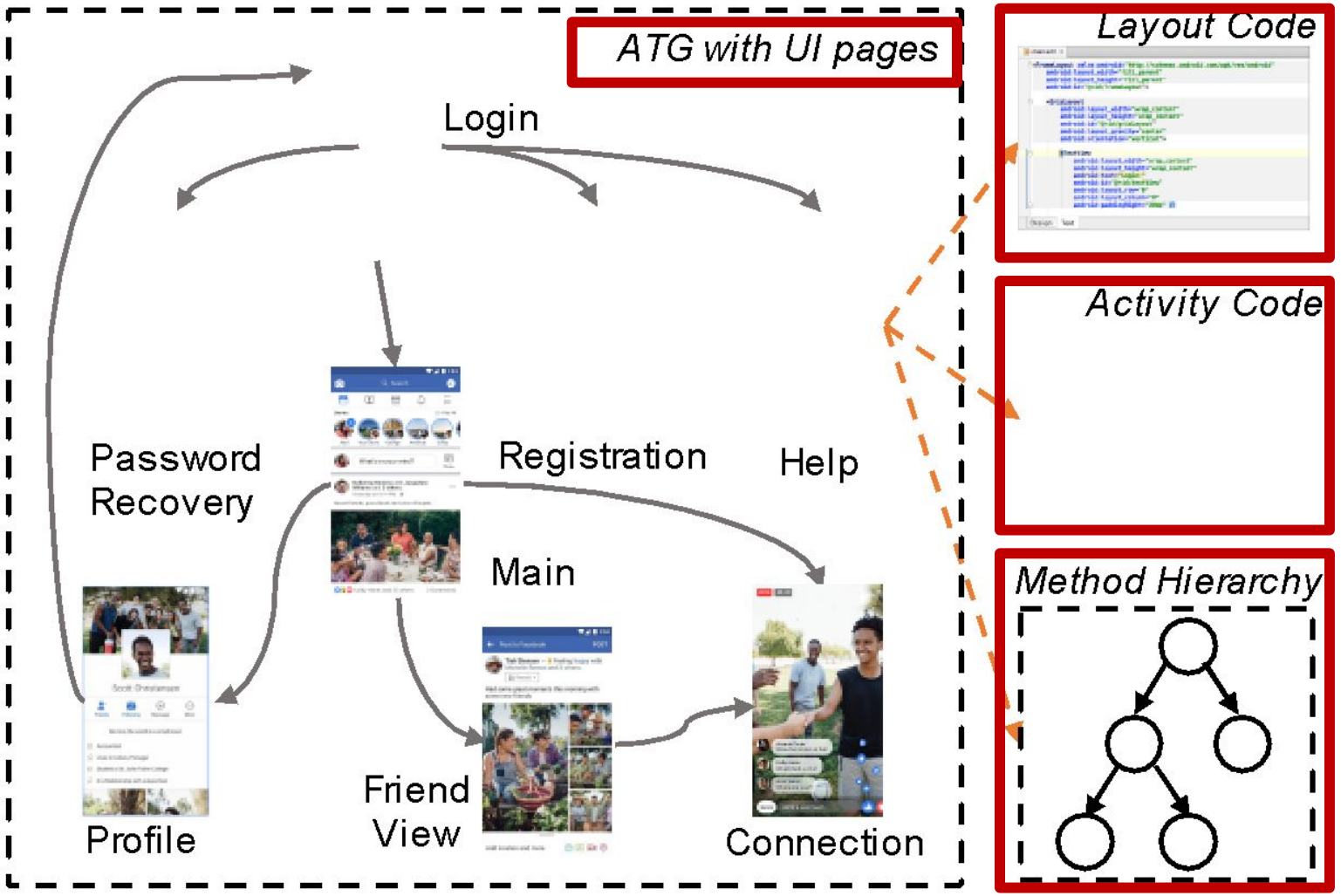
Storyboard

Storyboard of movies



Storyboard of apps

Storyboard of Android Apps



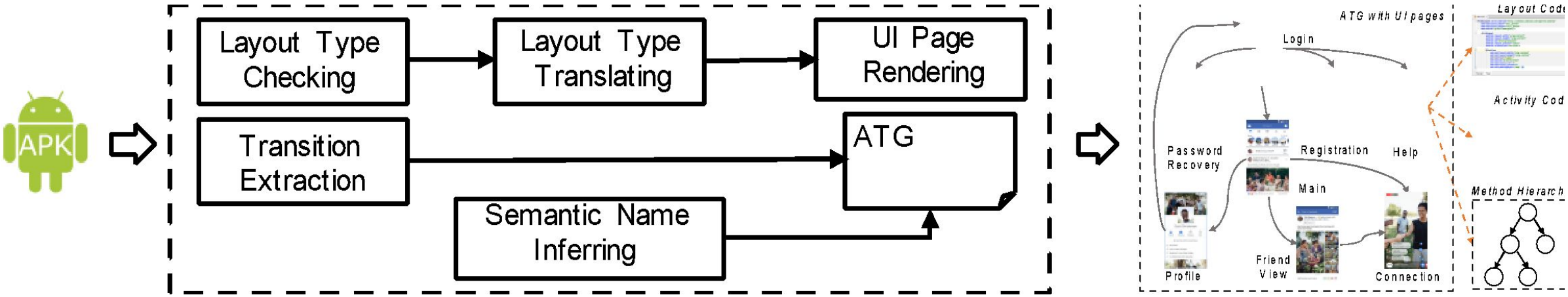
*ATG: Activity Transition Graph

Challenges

- ✔ ATGs* are usually incomplete due to the limitation of current static analysis tools (e.g., IC3 [1])
- ✔ A pure static approach may miss parts of UIs that are dynamically rendered.
- ✔ The obfuscated activity names lack the semantics of the corresponding functionalities.

[1] Octeau et al., “Composite constant propagation: Application to Android intercomponent communication analysis,” in ICSE 2015.

Our Solution - StoryDroid



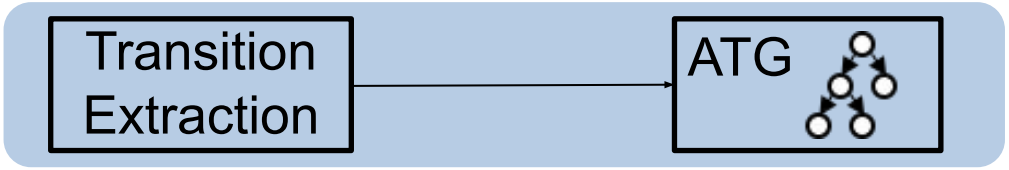
1. ATG Extraction
2. UI Page Rendering
3. Semantic Name Inferring

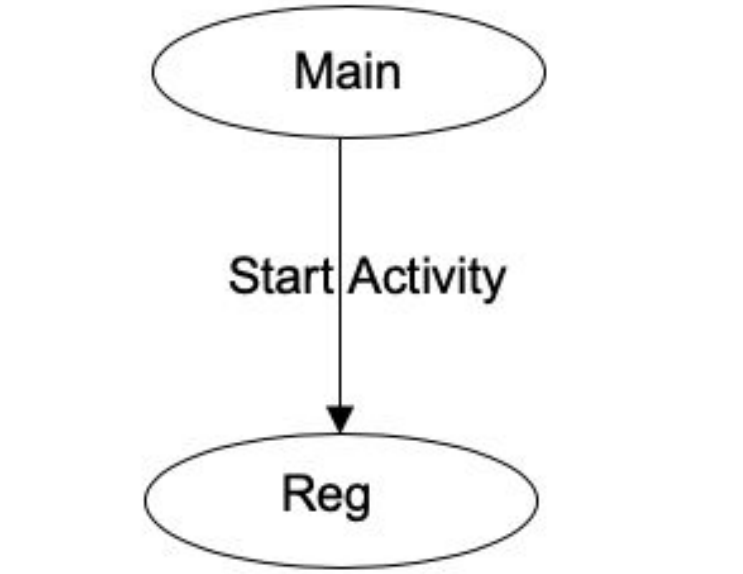
StoryDroid – Activity Transition Extraction

StoryDroid Enhances the ATG extraction ability of IC3, especially for fragments and inner classes.

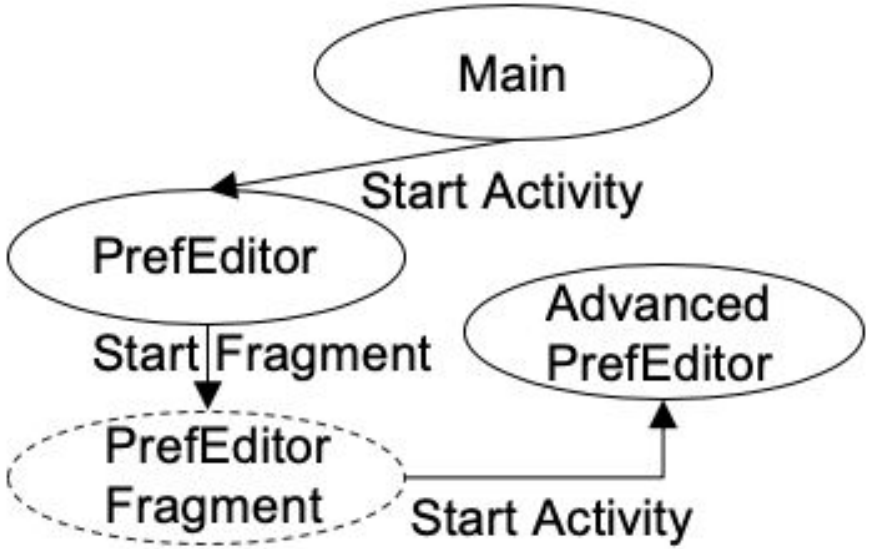
StoryDroid leverages control- and data-flow analysis to obtain relatively complete ATG.

Activity Transition Extraction

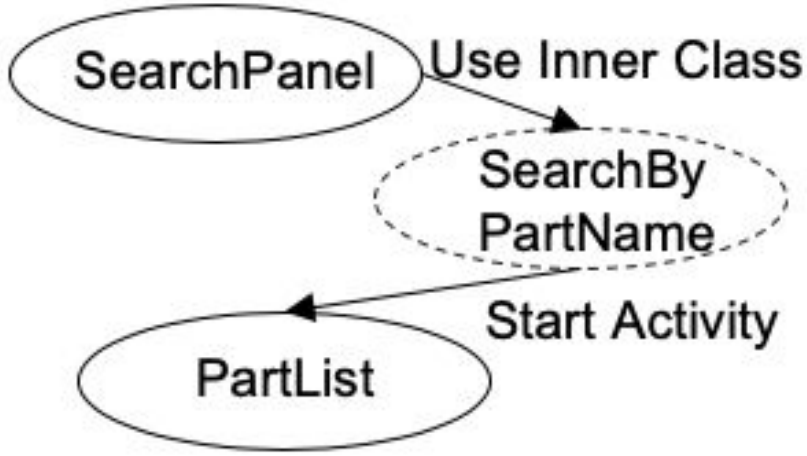




(a) Transitions between activities



(b) Transitions with Fragment



(c) Transitions with Inner Class

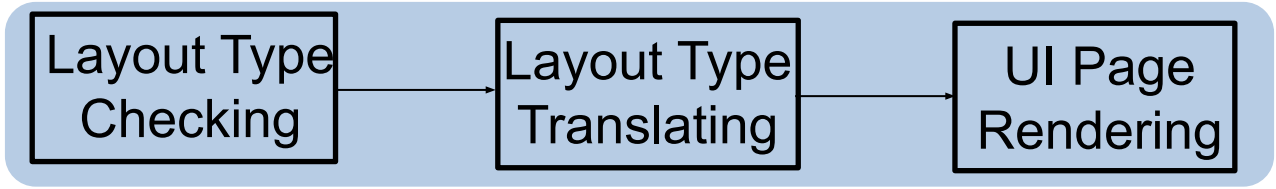
Main -> Reg

Main -> PrefEditor -> AdvancedPrefEditor

SearchPanel -> PartList

StoryDroid – UI Page Rendering

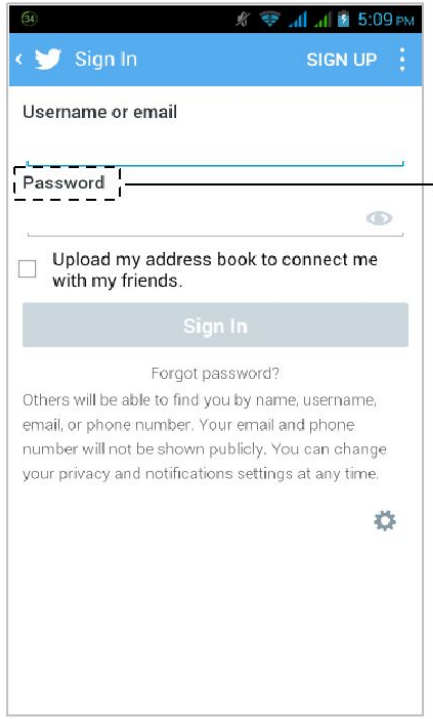
StoryDroid translates dynamic and hybrid layouts to static layout (if needed) to render UI pages that users interact with.



UI Page Rendering

Layout Type Checking → Layout Type Translating → UI Page Rendering

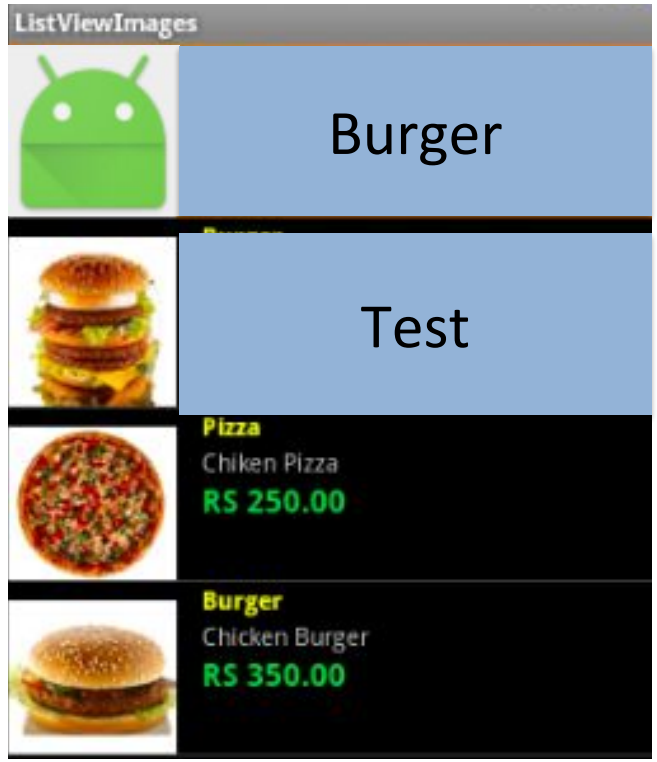
Layouts




```
1  // Static Layout
2  <TextView
3      android:id="@+id/text"
4      android:text="Password">
5  </TextView>
6
7  // Dynamic Layout
8  RelativeLayout r = new RelativeLayout();
9  TextView tv = new TextView();
10 tv.setText("Password");
11 r.addView(tv);
12
13 // Hybrid Layout
14 // main_act refers to a static XML file
15 LayoutInflater li = LayoutInflater.form();
16 View view = li.inflate(R.layout.main_act);
```

Layout Type Translation

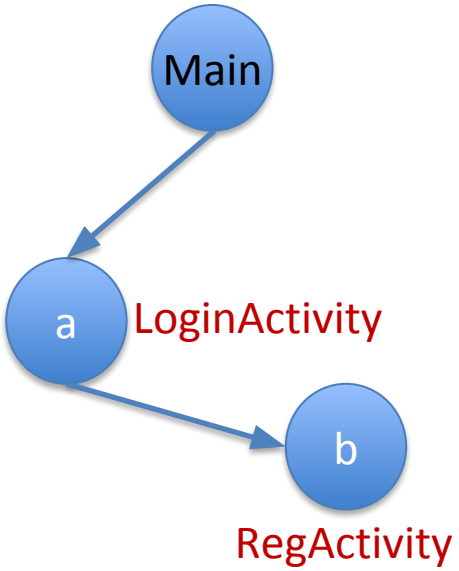
ListView

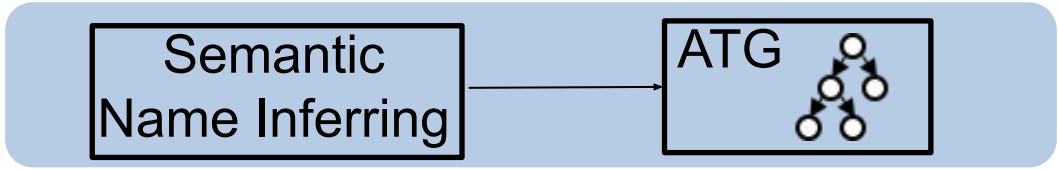


Adapter data rendering

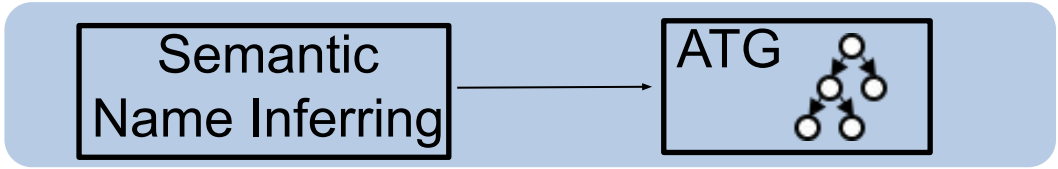
StoryDroid – Semantic Name Inferring

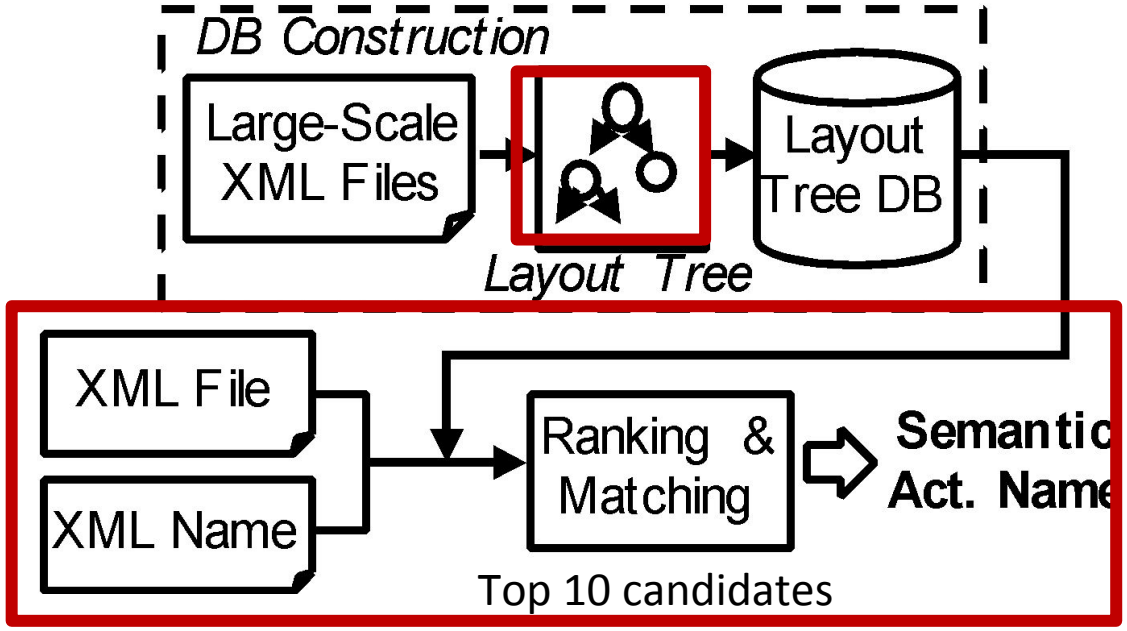
StoryDroid infers the semantic name for the obfuscated activity names by layout comparison.



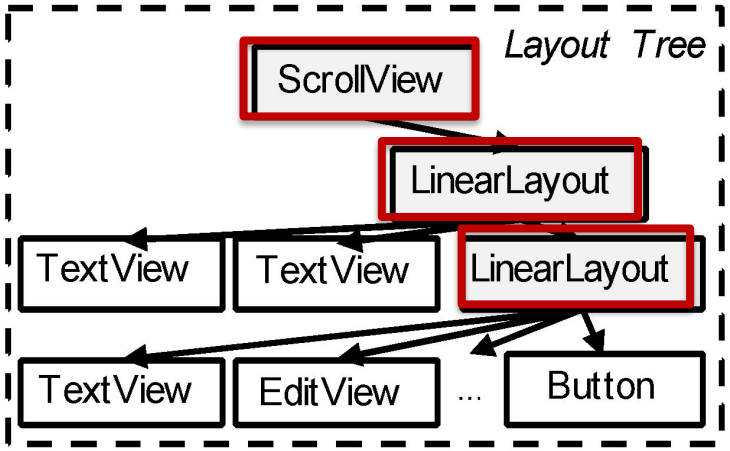


StoryDroid – Semantic Name Inferring





Layout Tree:

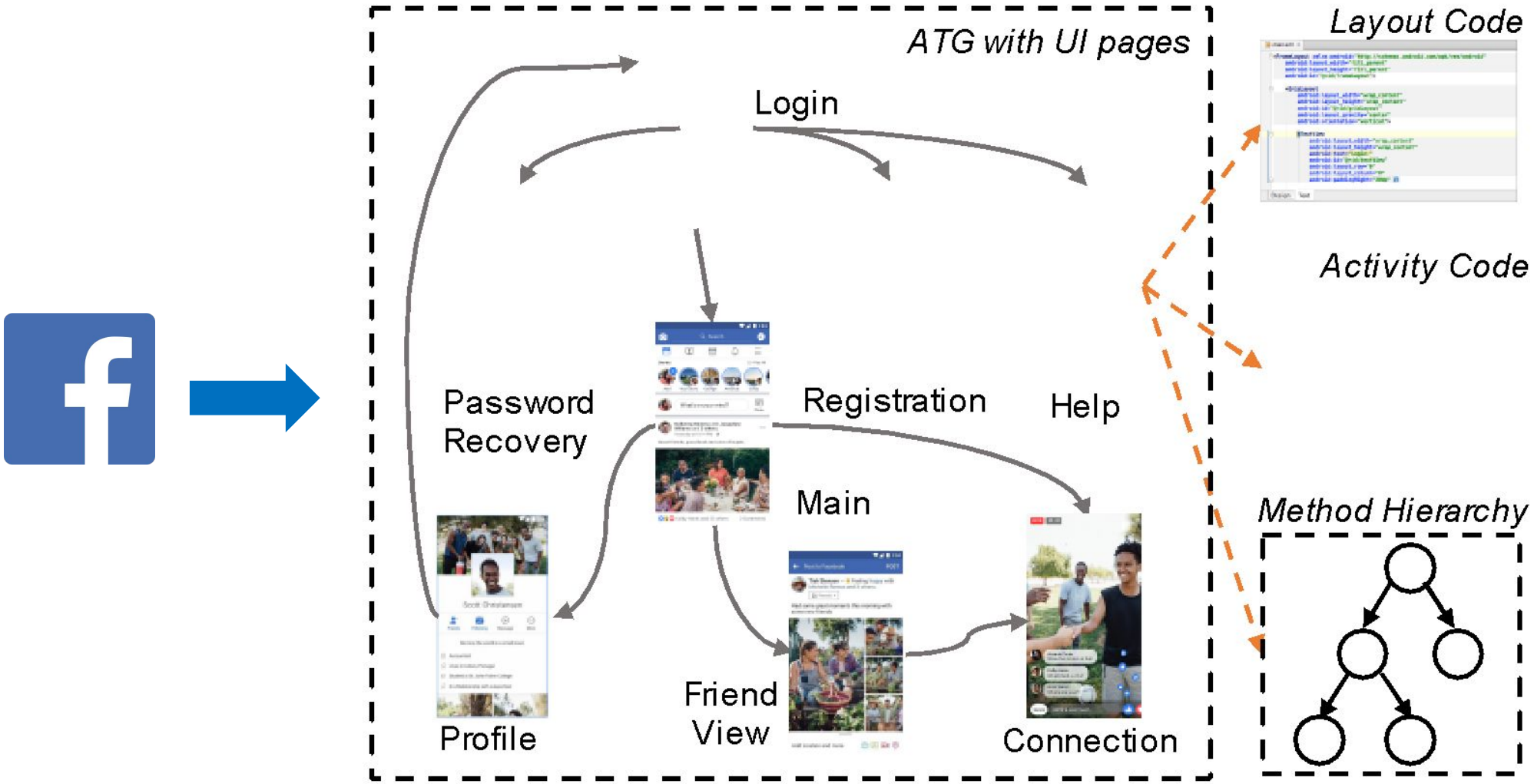


Layout Tree DB:

4,426 F-Droid apps

13,792 layout trees

Automated Generation of Storyboard



Effectiveness Evaluation - Research Questions

- RQ1: Can StoryDroid extract a more complete ATG for an app, and achieve better activity coverage than the dynamic testing tool (i.e., Stoat)?
- RQ2: Can StoryDroid render UI pages with high similarity compared with the real screenshots?
- RQ3: Can StoryDroid infer semantic names for obfuscated activities?

Effectiveness Evaluation - RQ1

Can StoryDroid extract a more complete ATG for an app, and achieve better activity coverage than the dynamic testing tool (i.e., Stoat)?

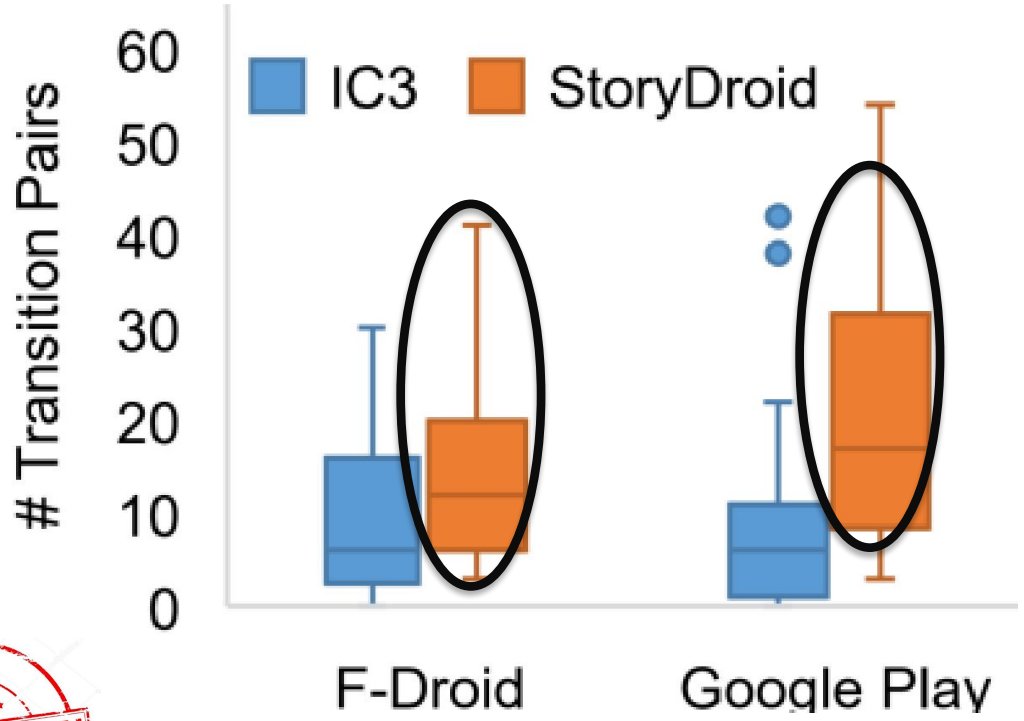
Effectiveness Evaluation - RQ1

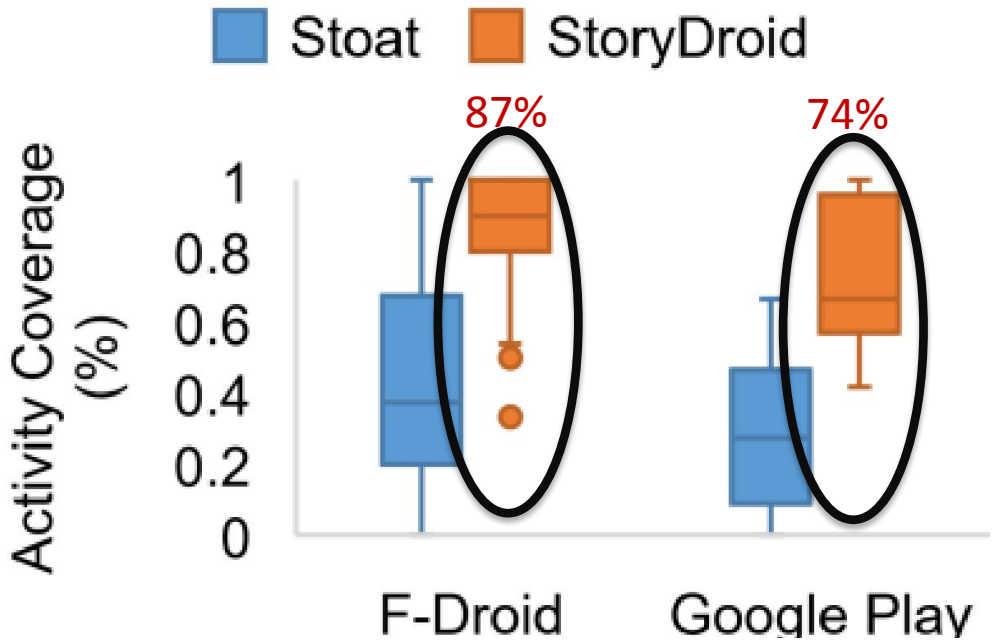
- Self-developed 10 apps
- Capability of handling fragments and inner classes

App ID	Feature	#Transition pairs	#Identified by IC3	#Identified by StoryDroid
1	Activity	14	14	14
2		13	13	13
3	Inner Class	13	-	13
4		13	-	13
5	Fragment	13	-	13
6		13	-	13
7	Activity & Inner Class	13	1	13
8		13	1	13
9	Activity & Fragment	10	1	10
10		10	1	10

Effectiveness Evaluation - RQ1

- 100 apps (i.e., 50 F-Droid and 50 Google Play)
- Transitions pairs and activity coverage





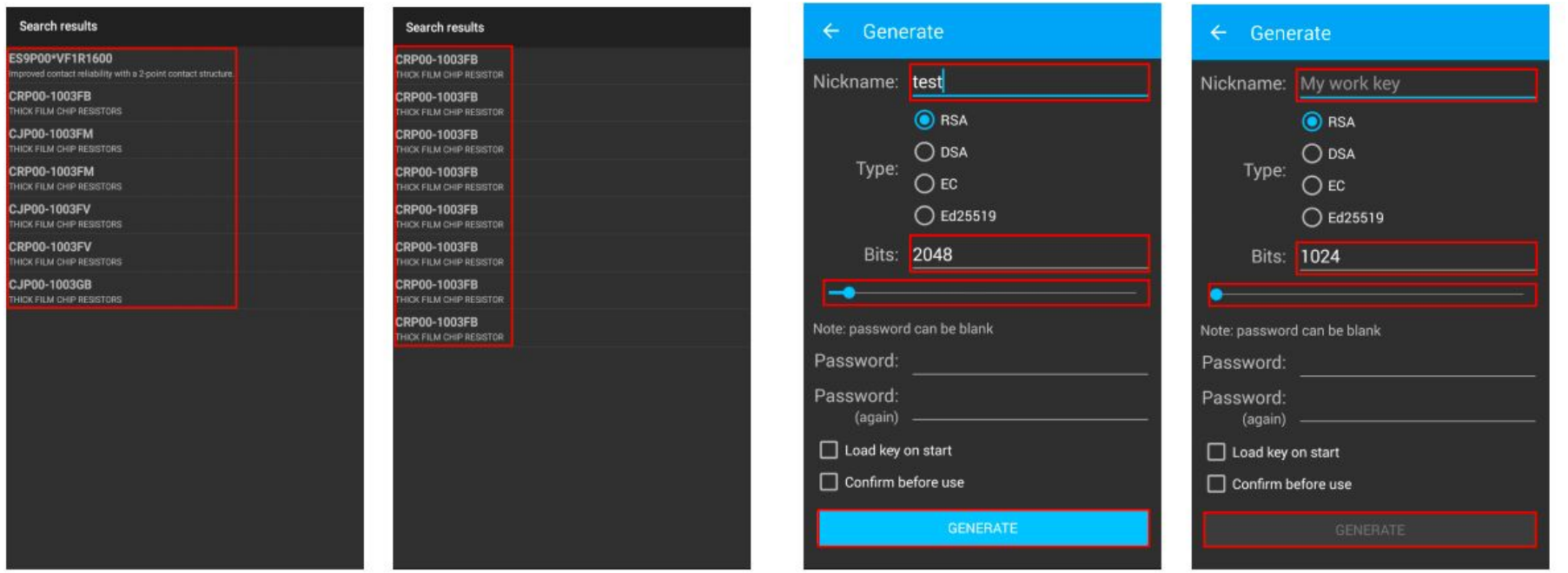
StoryDroid outperforms IC3 on ATG extraction and covers 2 times more activities than Stoat with less time.

Effectiveness Evaluation - RQ2

Can StoryDroid render UI pages with high similarity compared with the real screenshots?

Effectiveness Evaluation - RQ2

- Similarity compared with the real screenshots
- Metrics: MSE (Mean Squared Error) & MAE (Mean Absolute Error)



(a) Real page (b) Our rendered (c) Real page (d) Our rendered

CONCLUSION

StoryDroid can render UI pages with high similarity (84%) to the real ones in our experiments.

Effectiveness Evaluation - RQ3

Can StoryDroid infer semantic names for obfuscated activities?

Effectiveness Evaluation - RQ3

- 92 out of 100 activity names

Ground Truth Act. Name	Rank in Candidates	Corresponding XML Name	Inferred by StoryDroid
AboutAct.	1	about	AboutAct.
HelpAct.	2	activity_help	HelpAct.
PersonalInfoAct.	3	content_extended_title	WizardAct.
LoginAct.	3	login	LoginAct.
ContactAct.	1	contact_list	ContactListAct.
SearchAct.	4	grid_base	Searcher
SettingAct.	1	setting_container	SettingAct.
ShareAct.	1	activity_share	ShareAct.
SplashAct.	3	activity_splash	SplashAct.
TrackListAct.	1	list_view	TrackListAct.

StoryDroid can infer semantic names with high accuracy for obfuscated activity names.

Usefulness Evaluation

Whether StoryDroid can help explore and understand the functionalities of apps effectively?

Usefulness Evaluation – User Study

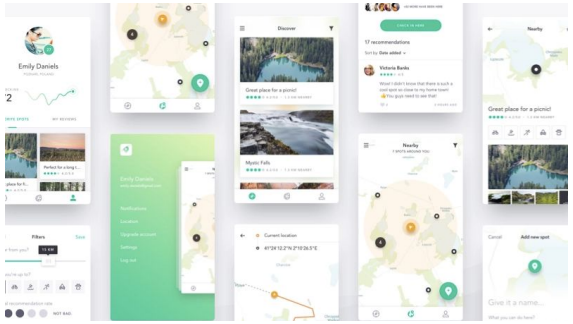
1. 4 apps with different number of activities (12-15 activities) from 2 categories (i.e., finance and tool), each category contains 2 apps
2. 8 participants including post-docs, Ph.D., and masters
3. For each category, each participant explored one app with StoryDroid, and the other without StoryDroid.

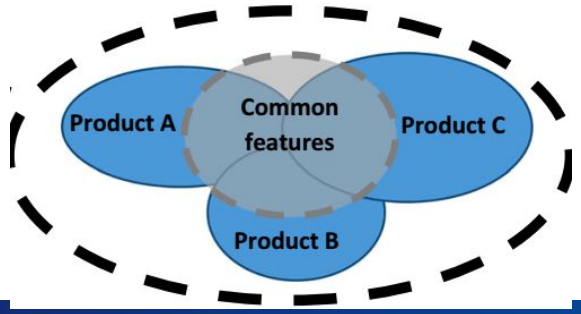
Metrics	Manual Exploration	StoryDroid
Time (min)	5.2	2.5
Coverage	40.8%	86.5%
Satisfactoriness (1-5)	4.2	4.4

Compared with manual exploration, StoryDroid achieves 2 times more activity coverage with less time cost to help understand the app functionalities.

Future applications based on StoryDroid

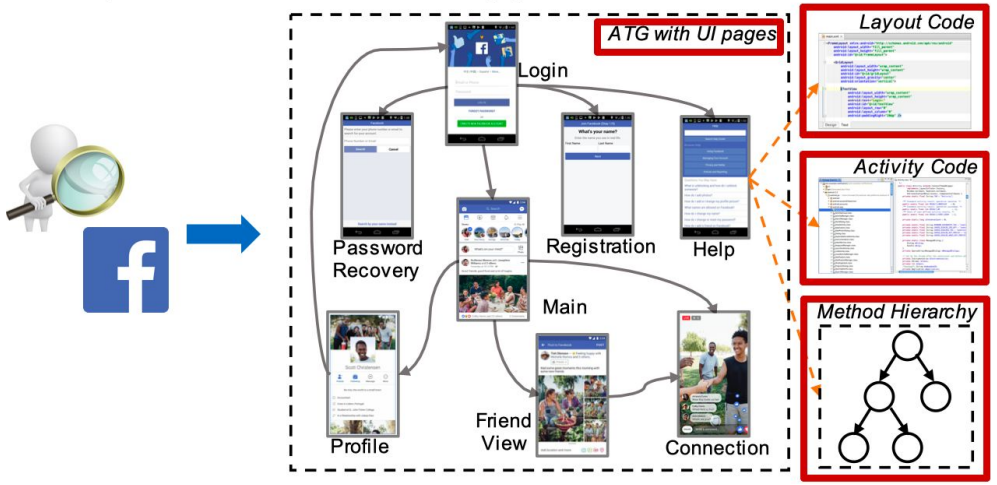
- ✔ Recommendation of UI design and code
- ✔ Guiding regression testing of apps
- ✔ Extracting commonalities across apps



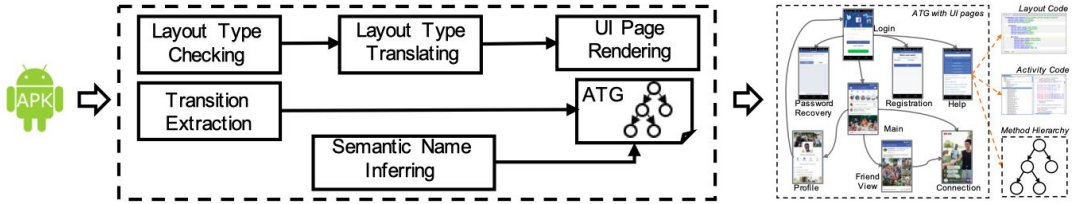


Summary

Storyboard of Android Apps



Our Solution - StoryDroid



① ATG Extraction
② UI Page Rendering
③ Semantic Name Inferring

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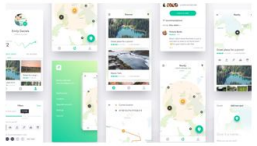

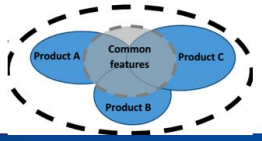

Thanks and Questions？

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