Large-scale Analysis of Framework-specific Exceptions in Android Apps

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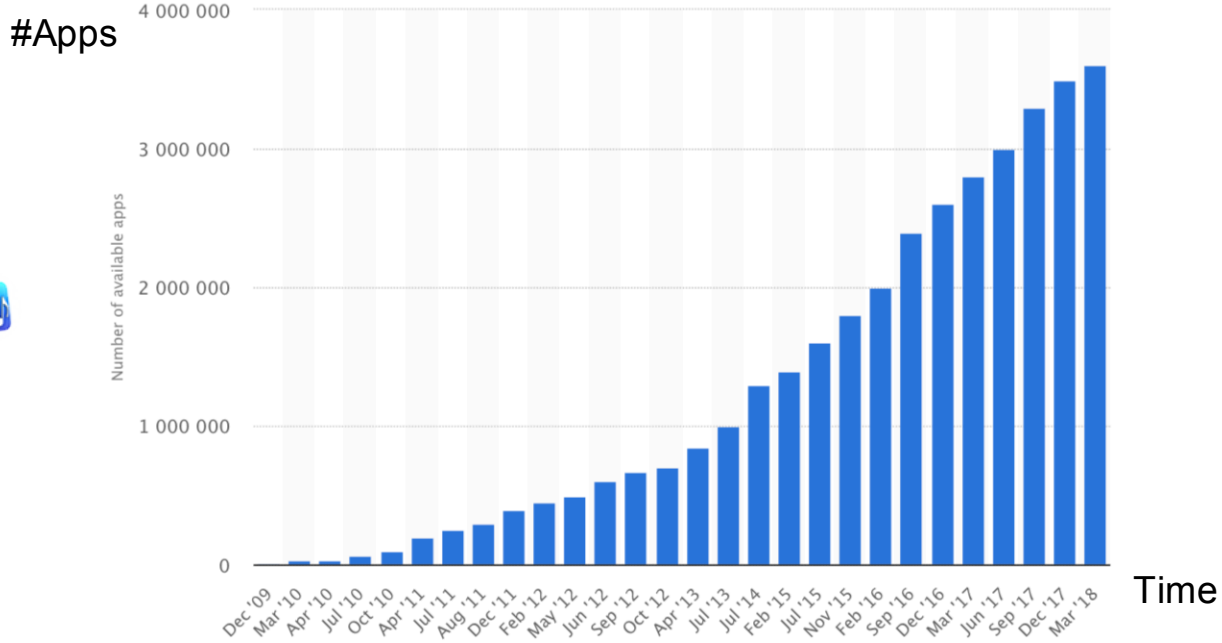
Gothenburg, Sweden

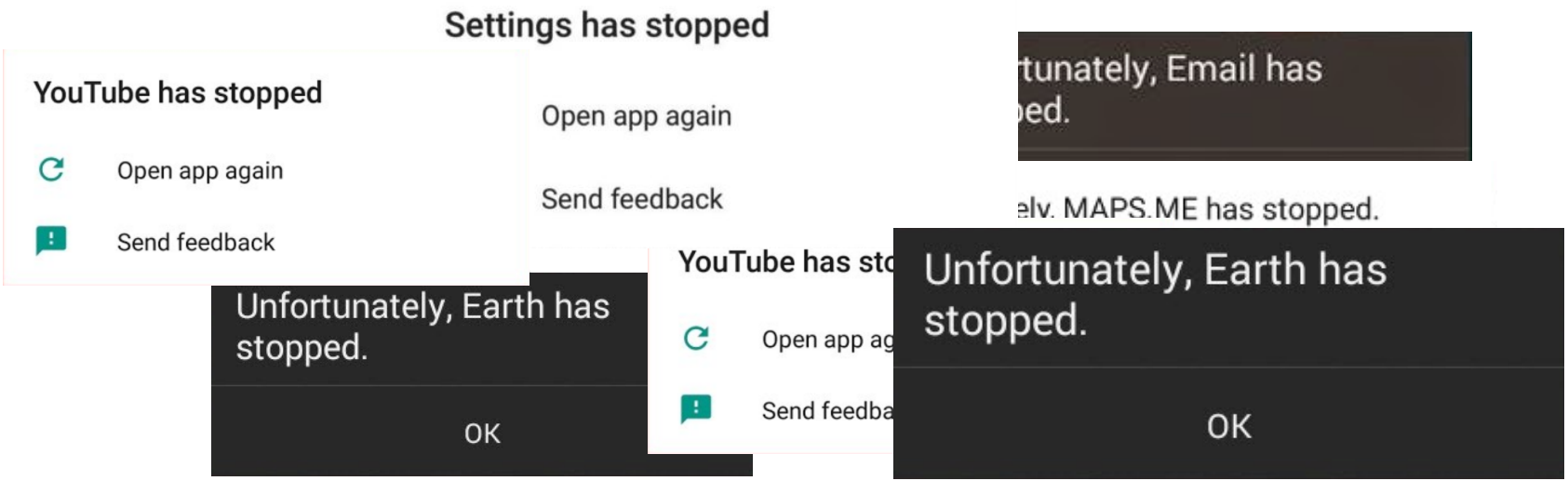
Mobile app is continuously increasing



[statista.com]

One of the key priority is to prevent fail-stop errors, e.g., crash

However……



Apps still suffer from crashes.

Customer complaints

A Lee-Koo

★★☆☆☆ 30 May 2018

Keeps crashing on Android 9 Developer Preview 2, please fix

walter itsadavisthang Youwouldntunderstand

★★☆☆☆ 25 May 2018

Keeps crashing, works shotty !

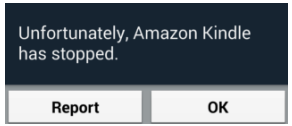
Brittonee Deleveaux

★☆☆☆☆ 27 May 2018

?241

Good for socializing with friends and family but becoming too strict and bias on behavior standards. App now crashes a lot too. Some people are targeted to be banned for 30 days and some are not penalized for the same infraction. Bans cannot be challenged and Facebook carelessly blocks you from

Framework-specific Crash for Android Apps




```
java.lang.RuntimeException: Unable to resume activity {*}:
java.lang.NumberFormatException: Invalid double: “”
        at android.app.ActivityThread.performResumeActivity(…)
        ….
Caused by: java.lang.NumberFormatException: Invalid double:“”
        at java.lang.StringToReal.invalidReal(StringToReal.java:63)
        at java.lang.StringToReal.parseDouble(StringToReal.java:248)
        ….
```

Root exception

Crash signaler

An example of exception trace

Crash Signaler ⇨

- **App**
- **Framework**
- **Lib**

NOTE: We do not consider exceptions caused by the bugs of framework itself.

With the understanding of framework crashes

Developers: avoid and fix crashes

Researchers: improve bug detection tools

However, existing studies on functional bugs analysis:

- Small scale (AST'11, ICST'14)
- Different goals (ICST'14, MSR'15)

  (1) generate testing oracles

  (2) investigate bug hazards of exception-handling code

Analyzing (framework-specific) crashes is challenging

- *Lack of comprehensive dataset*
  - *No publicly available data*
  - *Only 16% issues contain exception traces on Github and Google Code*

- *Lack of tool support*
  - *Crash reproducing tools*
  - *Failure localization tools*

- *Substantial human effort*
  - *Require understanding of Android framework*

Contribution

- First empirical study to characterize Android framework-specific exceptions
  - 11 fault categories
- Evaluate the state-of-the-art bug detection techniques
  - Static & dynamic tools
- Prototype tools to demonstrate the usefulness of findings
  - Stoat+ & Exlocator
- Publicly available dataset

Data Collection

2174

F-Droid (Github & Google code apps)

Crawling

Testing

GitHub Google code {P}

- 6,588 unique traces from issues and comments of 583 apps
- 613 fixing commits

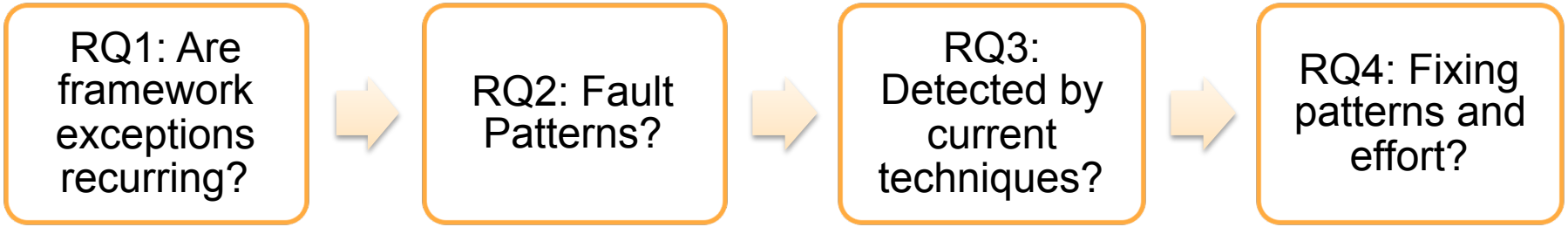
- ✓ Monkey
- ✓ Sapienz
- ✓ Stoat

Each app runs for 3h

4 months in total

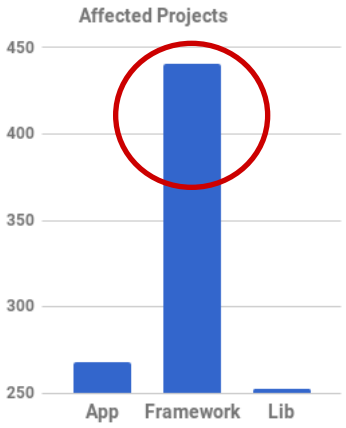
- 9,722 unique traces

Research Questions

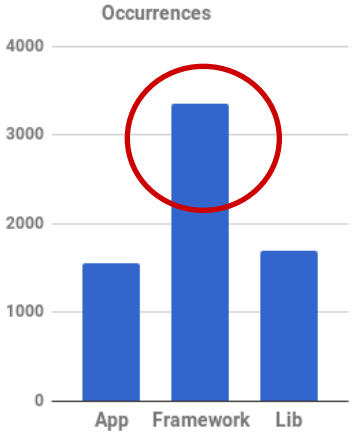


RQ1: Are framework exceptions recurring?

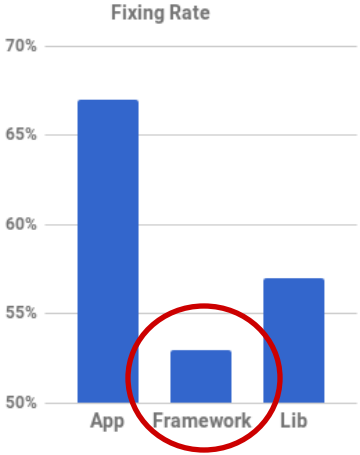
Based on 6,588 unique exceptions from Github and Google code



Affected projects



occurrences

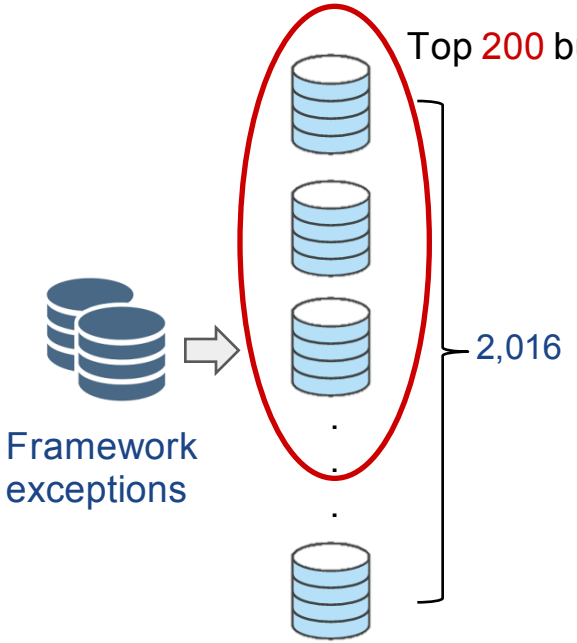


Fixing rate

Yes, framework exceptions are more recurring and pervasive

RQ2: Taxonomy of Framework Exceptions

Bucket: repository for exceptions that are thrown from the same location of Android framework



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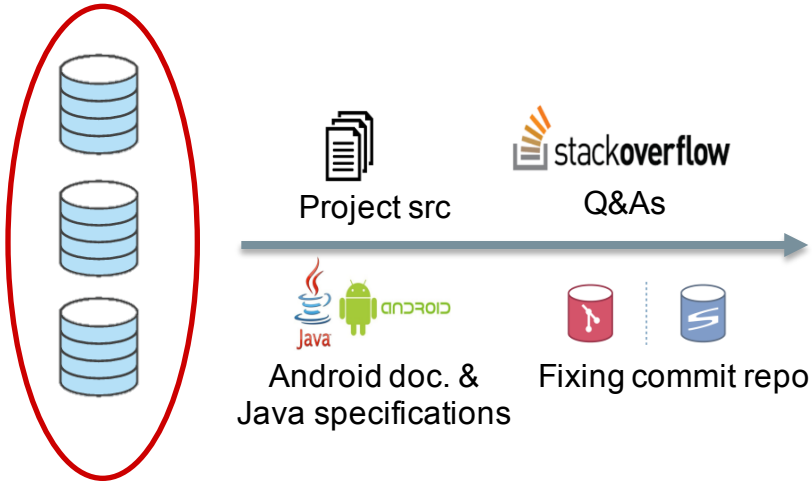


11 fault categories covering 84.6% of all framework exceptions

RQ2: Taxonomy of Framework Exceptions

Category	Occurrence	#S.O. posts
API Updates and Compatibility	68	60
XML Layout Error	122	246
API Parameter Error	820	819
Framework Constraint Error	**383**	**1726**
Index Error	950	218
Database Management Error	128	61
Resource-Not-Found Error	1303	7178
UI Update Error	327	666
Concurrency Error	372	263
Component Lifecycle Error	**608**	**1065**
Memory/Hardware Error	**414**	**792**

Developers make more mistakes on Lifecycle Error, Framework Constraint Error and Memory/Hardware Error.

RQ3: Auditing bug detection tools

Static Tools → **75** different exception instances from 11 categories

Tools	Android support	# Detected (out of 75 exceptions)	# Rules for Android
Lint	✓	**4**	281
FindBugs	✓	0	0
PMD	✓	0	3
SonarQube	✓	0	0

- Existing static analysis tools are ineffective in detecting framework exceptions

RQ3: Auditing bug detection tools

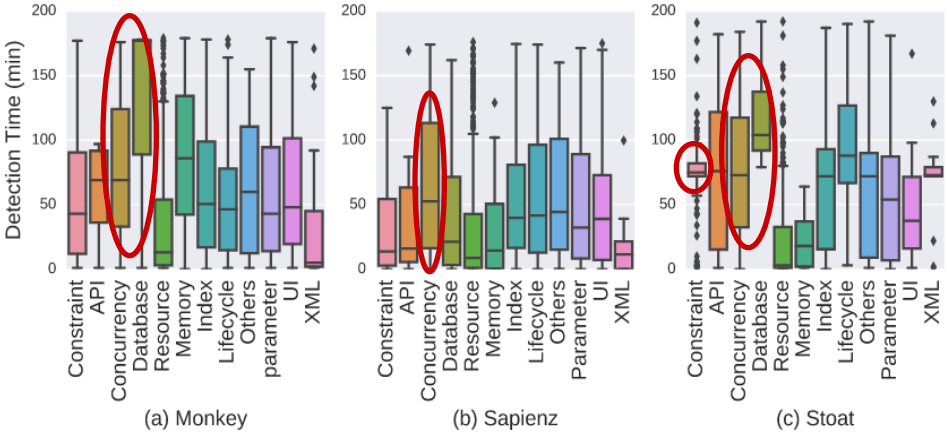
Dynamic Tools

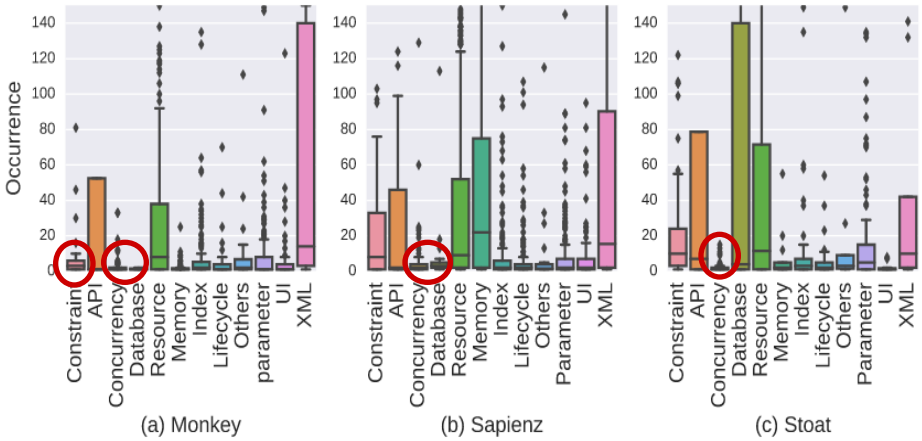
- 2104 apps (4560 versions)
- Each runs for 3h

Tools	Approach	# unique framework exceptions
Monkey	Random	1842
Sapienz	Search-based	2342
Stoat	Model-based	1438

Metrics: Detection time & Occurrence

RQ3: Auditing bug detection tools





Detection time: The time of detecting an exception for the first time

Occurrence: The times of an exception detected during 3 hours

- Dynamic testing tools are still far from effective in detecting database, framework constraint and concurrency errors

RQ4: Fixing Patterns

1. Refine Conditional Checks →

```
+    if(…){
        ……
+    }
```

2. Move Code into Correct Thread →

Worker thread		Main thread
UI update	→	UI update

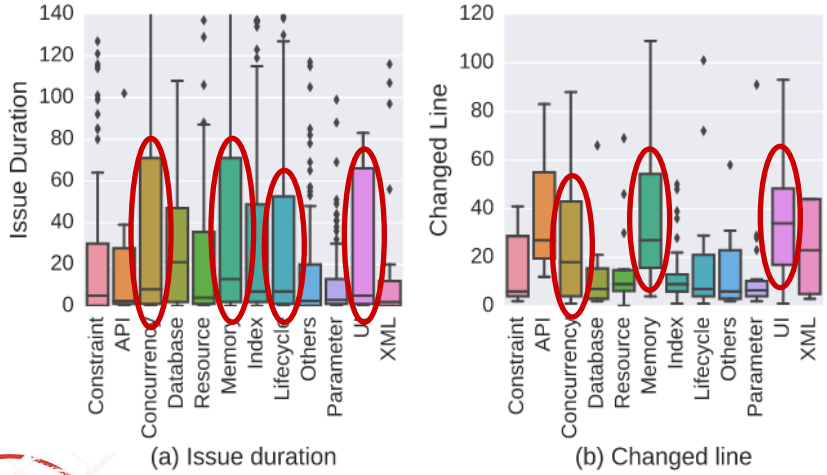
3. Work in Right Callbacks →

onCreate()	onstop()		onStart()	onStop()
register	unregister	→	register	unregister

4. Adjust Implementation Choices → Code refactoring

RQ4: Fixing Efforts

- Issue duration: The time cost to fix the issue (day)
- Changed line: Exclude "//...", "@Override", "import *.*"
- Closing rate: The percent of issues being closed



Category	Closing Rate
API Updates and Compatibility	93.9%
XML Layout Error	93.2%
API Parameter Error	88.5%
Framework Constraint Error	87.7%
Index Error	84.1%
Database Management Error	76.8%
Resource-Not-Found Error	75.3%
UI Update Error	**75.0%**
Concurrency Error	**73.5%**
Component Lifecycle Error	**58.8%**
Memory/Hardware Error	**51.6%**

- Lifecyle, Concurrency, UI update and memory errors are more difficult to fix

Applications

(1) Improving Bug Detection

- Meaningful corner cases
  - e.g., “"” and “%”
- Enforce environment interplay
  - Screen rotation
  - Start an activity and quickly back
  - Put the app at background for a long time and navigate to it again

3 previously unknown bugs

- Parameter error
- UI update error
- Lifecycle error

https://github.com/tingsu/Stoat

Applications

(2) Enabling Exception Localization


```
java.lang.RuntimeException:  Unable  to resume activity {*}:
java.lang.NumberFormatException:  Invalid  double:  “”
   at  android.app.ActivityThread.performResumeActivity(…)
   ….
Caused  by: java.lang.NumberFormatException:  Invalid  double:“”
   at  java.lang.StringToReal.invalidReal(StringToReal.java:63)
   at  java.lang.StringToReal.parseDouble(StringToReal.java:248)
   ….
```

ExLocator

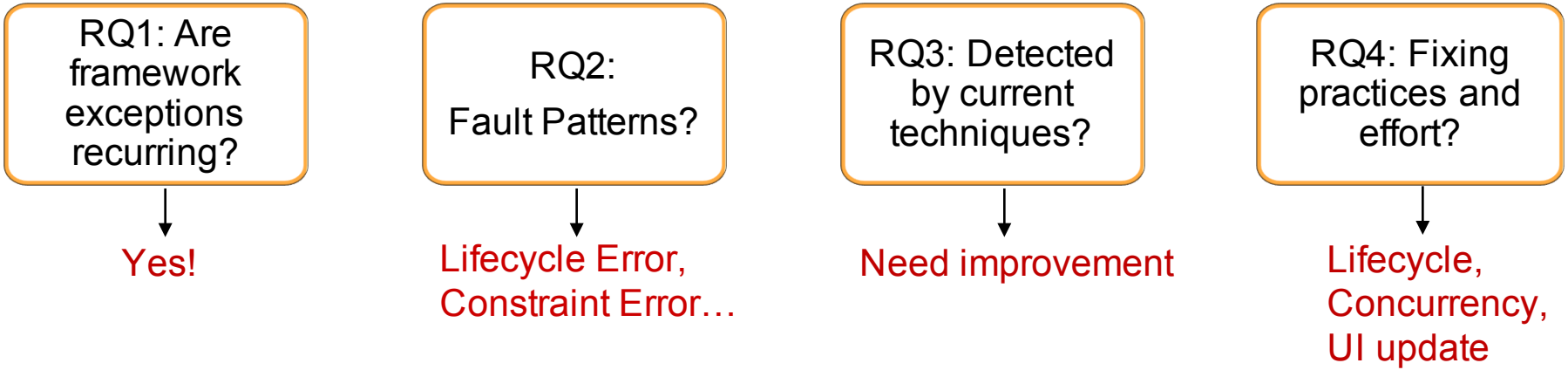
Report

1. Fault category
2. Root cause
3. Explanations
4. Fixing solutions

- Built on Soot
- Implemented 5 categories

25 out of 27 exceptions (92% precision) are correctly located by comparing the patches from the developers.

Conclusions



- First large-scale analysis of Android framework-specific exceptions
- Supporting follow-up research on bug detection, fault localization and patch generation
- Large-scale and reusable dataset available on https://crashanalysis.github.io/Dataset-CrashAnalysis

NTU is still hiring PhDs and post docs

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