User Review Mining for Assisting App Development

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User Reviews

App is absolute trash. Crashes every three seconds on a flagship stock Pixel 2 XL with zero problems with any other quality app.
User Reviews are Important

3,800,000 apps
Google Play

2,000,000 apps
App Store

669,000 apps
Windows Store

Ranking = (# of installs weighted for the past few hours) + (# of installs weighted for the past few days) + REVIEWS (star rating + number of reviews) + Engagement (# of times app opened etc.) + Sales ($)

https://appsposure.com/app-store-ranking-algorithms/
User Review Analysis is Important

App Install 58%
App Update 33%
App Purchase 36%

Users

Developers
"Optimism is an occupational hazard of programming: **Feedback** is the treatment"

--Kent Beck

- **App Bug**
- **App Feature**

Today my timeline is broken. I don't see posts of my friends just some random stuff from unknown sources. Fix it!

**App Reviews**
User Review Analysis is Challenging

- Massive review quantity

  ![WeChat](image1.png) 60,000 reviews/day

  ![Facebook](image2.png) 7,000+ reviews/day

  ![Netflix](image3.png) 2,000+ reviews/day
User Review Analysis is Challenging

- Massive review quantity
- Many non-informative reviews
- Short length and limited context
- Many noisy words
- Detailed app issues hard to be predefined

<table>
<thead>
<tr>
<th>Rate</th>
<th>Date</th>
<th>Review Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>August 7, 2018</td>
<td>Cant upload stories, its just stuck at posting, really bad app</td>
</tr>
<tr>
<td>5</td>
<td>August 7, 2018</td>
<td>Lol</td>
</tr>
<tr>
<td>4</td>
<td>August 7, 2018</td>
<td>Awsmmmmmmmm</td>
</tr>
<tr>
<td>1</td>
<td>August 7, 2018</td>
<td>Please fix</td>
</tr>
</tbody>
</table>
Traditional Study

• Keyword-based review retrieval
• Filtering out non-informative reviews
• Classifying reviews to predefined topics
• User sentiment prediction
• Device compatibility issue
• ...

Reduce the manual power!

Required predefined rules
Required labeled reviews
What Traditional Study Ignores

Focus on **static collection**, and ignore the **multiple dimensions** of reviews

<table>
<thead>
<tr>
<th>Rating</th>
<th>Name</th>
<th>Comment</th>
<th>Date</th>
<th>Language</th>
<th>Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>Untitled</td>
<td>Brief description of the updates would be good. Instead of &quot;A few minor updates to make Twitter an even better place&quot;.</td>
<td>Aug 07, 2018</td>
<td>English</td>
<td>7.56.1.1050</td>
</tr>
<tr>
<td>5.0</td>
<td>Untitled</td>
<td>A great app overall</td>
<td>Aug 07, 2018</td>
<td>English</td>
<td>7.56.0.1048</td>
</tr>
<tr>
<td>5.0</td>
<td>Untitled</td>
<td>Good</td>
<td>Aug 07, 2018</td>
<td>English</td>
<td>7.51.0</td>
</tr>
<tr>
<td>5.0</td>
<td>Untitled</td>
<td>My grandma got a face tatt</td>
<td>Aug 07, 2018</td>
<td>English</td>
<td>7.57.0.1051</td>
</tr>
</tbody>
</table>
Outline

- **Topic 1**: Online app review analysis for *detecting emerging app issues*
- **Topic 2**: Issue Prioritization *across different app platforms*
- **Topic 3**: Exploration on the effects of *in-app ads on user experience*
- Conclusion and future work
Outline

• **Topic 1:** Online app review analysis for detecting emerging app issues
  
  • **Topic 2:** Issue Prioritization across different app platforms
  
  • **Topic 3:** Exploration on the effects of in-app ads on user experience
  
  • Conclusion and future work
Outline

• **Topic 1**: Online app review analysis for detecting emerging app issues
  - Motivation
  - Framework of detecting emerging app issues
  - Evaluation
  - Summary
Outline

• **Topic 1**: Online app review analysis for detecting emerging app issues
  - Motivation
  - Framework of detecting emerging app issues
  - Evaluation
  - Summary
Emerging Issues

Definition:
An issue rarely appears in previous slice but is mentioned by a significant proportion of user reviews in current slice.
A Real Case for Emerging Issues

 Pokémon GO

 **UPDATE**

 **UPDATE**

 From Vocativ.com

 Serious!

 14,491

 1 star ratings on 8/1

 **UPDATE**

 4,669

 5 star ratings on 7/7

 From Vocativ.com
Reviews can Help

WHAT'S NEW
Version 3 of your Udacity App has arrived.
...gets a brand-new overview of your enrollment, and streamlined navigation...
V3.1.x
- Improved offline experience
- ...

Changelog
Our Task

App Reviews

IDEA (IDentifying Emerging App issues)

App Updates

Discovering emerging issues

Providing detailed issue interpretation

Visualizing issue changes over versions
Outline

• **Topic 1**: Online app review analysis for detecting emerging app issues
  - Motivation
  - Framework of detecting emerging app issues
  - Evaluation
  - Summary
IDEA Framework

A. Preprocessing

① AOLDA
② Anomaly Discovery

B. Emerging Topic Detection

① Candidate Extraction
② Topic Labeling

C. Topic Interpretation

D. Visualization

Version 

Review Stream
Adaptive On-Line LDA

Soft alignment of previous $\phi$

$$\beta_k^t = \sum_{i=1}^{W} \gamma_{k}^{t,i} \phi_k^{t-i}$$

$$\gamma_{k}^{t,i} = \frac{\exp(\phi_k^{t-i} \cdot \beta_k^{t-1})}{\sum_{j=1}^{W} \exp(\phi_k^{t-j} \cdot \beta_k^{t-1})}$$

Current Version

$$\phi_k^{t-w} \rightarrow \phi_k^{t-i} \rightarrow \phi_k^{t-1} \rightarrow \phi_k^{t}$$

Window size

App version

AOLDA Model
Anomaly Discovery

Jensen-Shannon Divergence:

\[ D_{JS}(\phi_k^t \mid \mid \phi_k^{t-1}) = \frac{1}{2} D_{KL}(\phi_k^t \mid \mid M) + \frac{1}{2} D_{KL}(\phi_k^{t-1} \mid \mid M) \]

\[ M = \frac{1}{2} (\phi_k^t + \phi_k^{t-1}) \]
IDEA Framework

A. Preprocessing
   ① AOLDA → ② Anomaly Discovery

B. Emerging Topic Detection
   →

C. Topic Interpretation
   ① Candidate Extraction → ② Topic Labeling

D. Visualization

Version $t$

Review Stream

Emerging Issues
## Topic Interpretation

### Top words of topic distribution

<table>
<thead>
<tr>
<th>Topic 1</th>
<th>Topic 2</th>
<th>Topic 3</th>
<th>Topic 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>comment</td>
<td>link</td>
<td>back</td>
<td>load</td>
</tr>
<tr>
<td>say</td>
<td>video</td>
<td>also</td>
<td>video</td>
</tr>
<tr>
<td>reply</td>
<td>open</td>
<td>button</td>
<td>even</td>
</tr>
<tr>
<td>try</td>
<td>work</td>
<td>change</td>
<td>work</td>
</tr>
<tr>
<td>error</td>
<td>description</td>
<td>go back</td>
<td>take</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

What is the issue behind those words?
Topic Labeling

Semantic Score

\[ Score_{sem}(l, \phi_k^t) = \text{sim}(l, \phi_k^t) - \frac{\mu}{K-1} \sum_{j \neq k} \text{sim}(l, \phi_j^t) \]

Sentiment Score

\[ Score_{sen}(l) = \exp\left(-\frac{r_l}{\log(h_l)}\right) \]

Total Score

\[ Score(l, \phi_k^t) = Score_{sem}(l, \phi_k^t) + \lambda \cdot Score_{sen}(l) \]
Outline

• **Topic 1:** Online app review analysis for detecting emerging app issues
  - Motivation
  - Framework of detecting emerging app issues
  - Evaluation
  - Summary
## Experiment Datasets

<table>
<thead>
<tr>
<th>App Name</th>
<th>Category</th>
<th>Crawled Platform</th>
<th>#Reviews</th>
<th>#Versions</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOAA Radar</td>
<td>Weather</td>
<td>App Store</td>
<td>8,363</td>
<td>16</td>
</tr>
<tr>
<td>YouTube</td>
<td>Multimedia</td>
<td>App Store</td>
<td>37,718</td>
<td>33</td>
</tr>
<tr>
<td>Viber</td>
<td>Communication</td>
<td>Google Play</td>
<td>17,126</td>
<td>8</td>
</tr>
<tr>
<td>Clean Master</td>
<td>Tools</td>
<td>Google Play</td>
<td>44,327</td>
<td>7</td>
</tr>
<tr>
<td>Ebay</td>
<td>Shopping</td>
<td>Google Play</td>
<td>35,483</td>
<td>9</td>
</tr>
<tr>
<td>Swiftkey</td>
<td>Productivity</td>
<td>Google Play</td>
<td>21,009</td>
<td>16</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
<td></td>
<td><strong>164,026</strong></td>
<td><strong>89</strong></td>
</tr>
</tbody>
</table>
Ground Truth

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Changelog</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.6</td>
<td>10-Sep-15</td>
<td>(1) Performance &amp; stability fixes for <strong>flawless location search</strong>.</td>
</tr>
</tbody>
</table>
| 3.7     | 16-Sep-15  | This update has a bunch of **iOS 9**-specific features for your convenience!  
(1) Get straight to the weather in your **favorite locations** as they now appear in **Spotlight search** results on your device.  
(2) .... |

**Word2Vec [Mikolov et al. 2013]**  
Sim>=0.6  
Hit
Metric

\[ \text{Precision}_{\text{Emerge}} = \frac{\text{Emerge} \cap \text{Changelog}}{\text{Emerge}} \]

\[ \text{Recall}_{\text{Label}} = \frac{\text{Label} \cap \text{Changelog}}{\text{Changelog}} \]

\[ F_{\text{hybrid}} = 2 \times \frac{\text{Precision}_{\text{Emerge}} \times \text{Recall}_{\text{Label}}}{\text{Precision}_{\text{Emerge}} + \text{Recall}_{\text{Label}}} \]
Validation

<table>
<thead>
<tr>
<th></th>
<th>NOAA Radar</th>
<th>Youtube</th>
<th>Viber</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Precision</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Recall</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>F-score</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Precision**

- **NOAA Radar**: 60.4%
- **Youtube**: 60.3%
- **Viber**: 29.6%

**Recall**

- **NOAA Radar**: 60.3%
- **Youtube**: 6.3%
- **Viber**: 23.1%

**F-score**

- **NOAA Radar**: 58.5%
- **Youtube**: 29%
- **Viber**: 6.3%
### IDEA’s Results

<table>
<thead>
<tr>
<th>Topic 1</th>
<th>v11.07</th>
<th>v11.10</th>
</tr>
</thead>
<tbody>
<tr>
<td>description box:</td>
<td>2.03</td>
<td>say playback error:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.12</td>
</tr>
<tr>
<td>Topic 2</td>
<td>user interface:</td>
<td>split screen:</td>
</tr>
<tr>
<td></td>
<td>1.25</td>
<td>1.23</td>
</tr>
</tbody>
</table>

### Emerging Issue

- **Topic 1**: I mean it work ... you would **click a link in the description** and it doesn’t even let me go through the next video: -0.050843
- **Topic 2**: But right now the lack of multitasking have actually .... : -0.79

### Sentence-level Issues

<table>
<thead>
<tr>
<th>Topic 1</th>
<th>v11.07</th>
<th>v11.10</th>
</tr>
</thead>
<tbody>
<tr>
<td>I can’t watch YouTube on my phone because the app won’t open and ... doesn’t work:</td>
<td>-1.03</td>
<td></td>
</tr>
</tbody>
</table>

### Phrase-level Issues

<table>
<thead>
<tr>
<th>Topic 2</th>
<th>v11.07</th>
<th>v11.10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add <strong>split view and slide over</strong> but no picture in picture:</td>
<td>-1.366723</td>
<td></td>
</tr>
</tbody>
</table>
Industry Practice

4/20+ Tencent apps

500~5,000 reviews per day

For 36,000 product reviews per version:

- ~160 reviews per second
- 1.02 GB on average

Tencent
Bugly Group

One PC with Intel(R) Xeon E5-2620v2 CPU (2.10 GHz, 6 cores) and 16GB RAM
Outline

• **Topic 1**: Online app review analysis for detecting emerging app issues
  - Motivation
  - Framework of detecting emerging app issues
  - Evaluation
  - **Summary**
Conclusion of Topic 1

• We first study emerging issues in app reviews.
• We propose ‘IDEA’ for effectively identifying emerging issues in both research and industry scenario in an end-to-end mode.
• We proposed to use changelogs for verification, which can also be used in other verification scenarios.
• We release our code for publicly available.
Outline

• **Topic 1:** Online app review analysis for detecting emerging app issues

• **Topic 2:** Issue Prioritization across different app platforms

• **Topic 3:** Exploration on the effects of in-app ads on user experience

• Conclusion and future work
Outline

• **Topic 2: Issue Prioritization across different app platforms**
  - Motivation
  - Framework of CrossMiner
  - Evaluation
  - Summary
Outline

• **Topic 2: Issue Prioritization across different app platforms**
  - Motivation
  - Framework of CrossMiner
  - Evaluation
  - Summary
Apps Distributed in Different Platforms

![Google Play](image1)

User Revenue

**Worldwide App Downloads - First Half 2018**

- $60B
- $50B
- $40B
- $30B
- $20B
- $10B
- $0

**Worldwide Gross App Revenue - First Half 2018**

- $40B
- $30B
- $20B
- $10B
- $0

1H 2017 | 1H 2018
---|---
Google Play | App Store
32.6B | 36.0B
13.2B | 15.0B
$17.8B | $22.6B
$9.1B | $11.8B
Differences of Platforms

Programming Languages:

User Experience:
It always can’t connect network.
The app sometimes crashes.
The UI is ugly.

Reviews in Different Platforms

Google Play

App Store

Windows

Developers

Design and maintain specifically

Reviews

Google Play

App Store

Windows
Seven Basic App Issues

- Battery
- Connection
- Spam
- Privacy
- Memory
- Crash
- UI
Outline

• **Topic 2: Issue Prioritization across different app platforms**
  - Motivation
  - Framework of CrossMiner
  - Evaluation
  - Summary
CrossMiner Framework

1. Preprocessing
   - A. Clean Review Extraction

2. Filtering
   - B. Keywords Generation
     - 3. Training Model
     - 4. Extracting Keywords
     - 5. Ranking Reviews

Visualization

Report
Extracting Keywords

Similar words for each issue based on word2vec:

\[ \text{similarity} = \frac{\sum_{i=1}^{n} I_i W_i}{\sqrt{\sum_{i=1}^{n} I_i^2} \sqrt{\sum_{i=1}^{n} W_i^2}} \]

Combined with clustering method:

<table>
<thead>
<tr>
<th>Issue</th>
<th>Similar Words</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery</td>
<td>battery, drain, usage, consumption, overheating, drainer, consume, cpu, power, ram, hog, electricity, drainage, charger, batter, standby, discharge, energy, deplete, memory, foreground</td>
</tr>
</tbody>
</table>
## Keyword List

<table>
<thead>
<tr>
<th>Issue</th>
<th>Keywords</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery</td>
<td>battery, drain, usage, consumption, overheat, drainer, consume, power, hog, electricity, drainage, charger, batter, standby, discharge, energy</td>
</tr>
<tr>
<td>Crash</td>
<td>crash, freeze, foreclose, lag, crash, stall, close, shut, laggy, glitch, hang, load, stuck, startup, buffer, open, lags, freeze, glitchy, buggy</td>
</tr>
<tr>
<td>Memory</td>
<td>memory, storage, space, gb, internal, gigabyte, ram, 6gb, occupy, 4gb, mb, 300mb, 8gb, 500mb, 16gb, byte, 5gb, gig, 2gb, 1gb, 1g</td>
</tr>
<tr>
<td>Network</td>
<td>network, connectivity, internet, consumption, wifi, connection, reception, conection, connect, signal, 4g, wi, 3g, broadband, fibre, lte, reconnecting, fi, wireless, reconnect, disconnect</td>
</tr>
<tr>
<td>Privacy</td>
<td>privacy, security, invade, safety, personal, policy, invasion, breach, protection, protect, private, disclosure, secure, unsafe, insecure, permission, fingerprint, encryption, violation, encrypt</td>
</tr>
<tr>
<td>Spam</td>
<td>spam, spammer, scammer, unsolicited, harassment, unwanted, bot, bombard, junk, scam, advertisement, pop-ups, scraper, hacker</td>
</tr>
<tr>
<td>UI</td>
<td>ui, interface, design, layout, gui, ux, clunky, redesign, aesthetic, navigation, usability, desing, sleek, appearance, aesthetically, intuitive, minimalistic, ugly, slick, graphic, unintuitive</td>
</tr>
</tbody>
</table>
Ranking Reviews

Ranking score defined as:

\[
score(t) = e^{-\sqrt{\frac{1}{\ln(n) + 1} + \frac{1}{\ln(n_t) + 1}}}\]

<table>
<thead>
<tr>
<th>Rank</th>
<th>User Review</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Seriously bad user experience and interface. Once you’ve liked or unliked</td>
<td>0.943</td>
</tr>
<tr>
<td></td>
<td>a song, there’s no way to go back even if you’ve made a mistake. I don’t</td>
<td></td>
</tr>
<tr>
<td></td>
<td>know why Spotify is so popular with such poor graphic design.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Clunky unintuitive interface missing basic and obvious music player features</td>
<td>0.914</td>
</tr>
<tr>
<td></td>
<td>You must get the basics right first before trying to push rubbish the</td>
<td></td>
</tr>
<tr>
<td></td>
<td>user doesn’t want.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Don’t like the new design, in the now playing view the artwork is smaller</td>
<td>0.890</td>
</tr>
<tr>
<td></td>
<td>to fit in the artwork on either side. I don’t care what’s on either end of</td>
<td></td>
</tr>
<tr>
<td></td>
<td>my current playing track, or at least show it in a way that doesn’t take up</td>
<td></td>
</tr>
<tr>
<td></td>
<td>artwork space. The album art is always an awesome part of the music’s</td>
<td></td>
</tr>
<tr>
<td></td>
<td>personality so it shouldn’t be minimised like this. Also the now playing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>bar at the bottom of the screen isn’t flat looking, looks like design from</td>
<td></td>
</tr>
<tr>
<td></td>
<td>windows XP. Not happy. An awesome service needs an awesome interface.</td>
<td></td>
</tr>
</tbody>
</table>

The top three reviews related to "UI".
Outline

• Topic 2: Issue Prioritization across different app platforms
  - Motivation
  - Framework of CrossMiner
  - Evaluation
  - Summary
Subject Apps

20 Apps

<table>
<thead>
<tr>
<th>App</th>
<th>Platform</th>
<th>Title</th>
<th>Review</th>
<th>Date</th>
<th>Star</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facebook</td>
<td>Google Play</td>
<td>Crashes</td>
<td>Crashes non stop</td>
<td>2015-10-22</td>
<td>1</td>
</tr>
</tbody>
</table>

Review # 2,637,438
Review # 1,687,003
Review # 338,875
Experimental Result

Percentage Distribution on Issues of Spotify Music

(a) Google Play

(b) App Store

(c) Windows Store
Performance Evaluation

Ranked Issues from Android Community of Spotify Music

<table>
<thead>
<tr>
<th>Rank</th>
<th>Views</th>
<th>User Feedback</th>
<th>Issue</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>56416</td>
<td>No internet connection available</td>
<td>Network</td>
</tr>
<tr>
<td>2</td>
<td>32495</td>
<td>No SD Card storage !!</td>
<td>Memory</td>
</tr>
<tr>
<td>3</td>
<td>24797</td>
<td>Spotify for Android causing massive battery drain and heating of phone</td>
<td>Battery</td>
</tr>
<tr>
<td>4</td>
<td>11315</td>
<td>Spotify crashes on Android</td>
<td>Crash</td>
</tr>
<tr>
<td>5</td>
<td>1796</td>
<td>Issues with Android UI context menu touch area</td>
<td>UI</td>
</tr>
<tr>
<td>6</td>
<td>197</td>
<td>Intrusive or what!!!!!!</td>
<td>Privacy</td>
</tr>
<tr>
<td>7</td>
<td>80</td>
<td>Tired of the push notification spam!</td>
<td>Spam</td>
</tr>
</tbody>
</table>

We use the well-known Normalized Discounted Cumulative Gain (NDCG):

\[
NDCG@k = \frac{DCG@k}{IDCG@k}
\]

NDCG evaluation results:

<table>
<thead>
<tr>
<th></th>
<th>Android</th>
<th>iOS</th>
<th>Windows Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDGC@7</td>
<td>0.943</td>
<td>0.911</td>
<td>0.982</td>
</tr>
</tbody>
</table>
Platform Comparison

Average Percentage Distributions on Issues for Different Platforms

$\text{p-value of ANOVA: \ 0.012 < 0.05}$

Cross-platform issue Distributions are Significantly Different.
Outline

• **Topic 2: Issue Prioritization across different app platforms**
  - Motivation
  - Framework of CrossMiner
  - Evaluation
  - **Summary**
Conclusion of Topic 2

• We propose a framework CrossMiner to extract issue-related keywords comprehensively from real user reviews.

• We discover the differences on different platforms from users’ perspective.

• We demonstrate that our framework reflects the importance of user concerns accurately.
Outline

- **Topic 1:** Online app review analysis for detecting emerging app issues
- **Topic 2:** Issue Prioritization across different app platforms
- **Topic 3:** Exploration on the effects of in-app ads on user experience
- Conclusion and future work
Outline

• **Topic 3: Exploration on the effects of in-app ads on user experience**
  - Motivation
  - Workflow of in-app ads exploration
  - Evaluation
  - Summary
Outline

• **Topic 3:** Exploration on the effects of in-app ads on user experience
  - Motivation
  - Workflow of in-app ads exploration
  - Evaluation
  - Summary
In-App Ads are Important

% ad revenue from mobile

<table>
<thead>
<tr>
<th>Year</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
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</thead>
<tbody>
<tr>
<td>%</td>
<td>11%</td>
<td>45%</td>
<td>65%</td>
<td>77%</td>
<td>83%</td>
<td>88%</td>
</tr>
</tbody>
</table>
Apps with Ads are Growing

Display ads on mobile growth trajectory

User Experience Matters

Top 7 Reasons Why People Uninstall Apps

- Crash
- Slow Launch
- Intrusive Ads
- Bad UI/UX
- Annoying Notifications
- Forced Social Logins
- Complex Registration
Ads Cause Much Performance Cost

+Ads

-16% 2.5~2.1 hours

+22%

+56%

+200%
Our task

Mobile Ads

Users
Outline

• **Topic 3: Exploration on the effects of in-app ads on user experience**
  - Motivation
  - Workflow of in-app ads exploration
  - Evaluation
  - Summary
Workflow of In-App Ads Exploration

1. Preprocessing
2. Phrase Retrieval
3. Issue Extraction
4. Sentence Grouping
5. Issue Grading

Performance Issue Grading (Step 1)

Correlation Analysis (Step 3)

Instrumented Phone
Install

Apps

Crawl

App Details & Reviews

Google Play

Performance Cost Measurement (Step 2)

Memory
CPU
Network
Battery
Correlation Analysis

Graded User Concerns
- Memory
- CPU
- Network
- Battery

Measured Performance Cost
- Memory
- CPU
- Network
- Battery

- Pearson Correlation Computation (PCC)
- Spearman’s Rank Correlation (SRC)

$n$ subject apps
Outline

• **Topic 3: Exploration on the effects of in-app ads on user experience**
  - Motivation
  - Workflow of in-app ads exploration
  - **Evaluation**
  - Summary
## Correlation Analysis Result

<table>
<thead>
<tr>
<th>Cost Type</th>
<th>Memory</th>
<th>CPU</th>
<th>Network</th>
<th>Battery</th>
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<tbody>
<tr>
<td></td>
<td>$r$-score</td>
<td>$p$-value</td>
<td>$r$-score</td>
<td>$p$-value</td>
</tr>
<tr>
<td>PCC</td>
<td>0.132</td>
<td>0.578</td>
<td>0.166</td>
<td>0.482</td>
</tr>
<tr>
<td>SRC</td>
<td>0.372</td>
<td>0.105</td>
<td>0.213</td>
<td>0.366</td>
</tr>
</tbody>
</table>
User-Concerned Ad Issues

**Insight:**
- Choose ad SDKs that can recommend relevant ads;
- Avoid pop-up ads;
- Avoid full-screen ads;
- Shorten the compulsory video ads.
Outline

• **Topic 3:** Exploration on the effects of in-app ads on user experience
  - Motivation
  - Workflow of in-app ads exploration
  - Evaluation
  - Summary
Conclusion of Topic 3

- We provide detailed findings and insights captured from an extensive analysis on user feedback.

- We carry out the first empirical study to explore correlations between user concerns and performance costs of ads in practice.

- We make publicly available the source code for cost measurement and user review analysis.
Outline

• **Topic 1**: Online app review analysis for detecting emerging app issues

• **Topic 2**: Issue Prioritization across different app platforms

• **Topic 3**: Exploration on the effects of in-app ads on user experience

• Conclusion and future work
Thesis Contributions

User Review Mining

- Version 1

Varying App Issues

- Issue Tracking (AR-Tracker)
  - Chapter 3
- Prioritization (PAID)
  - Chapter 4
- Anomaly Detection (IDEA)
  - Chapter 5

App Platforms

- Issue Distribution (CrossMiner)
  - Chapter 6

App Performance

- In-App Ads Analysis
  - Chapter 7
Conclusion

- We design various frameworks and algorithms for observing issues along with versions, across platforms, and for specific app component.

- We conduct large-scale experiments on verifying the effectiveness of our frameworks in various applications.

- We develop several tools for developers to use in practice.
Future Work (1)

- Automatic user review reply.
Future Work (2)

- Review-based code localization.

Raw Logs

Log Parsing

Log Sequence Ranking

Supervised Training

Log Sequence Embedding

Log Identifier

Issue Embedding

App Issue Detection

Preprocessing

Raw Reviews

Raw Log Messages

Log Events

<table>
<thead>
<tr>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event1</td>
<td>BLOCKx NameSystem allocateBlock: *</td>
</tr>
<tr>
<td>Event2</td>
<td>Receiving block * src: * dest: *</td>
</tr>
<tr>
<td>Event3</td>
<td>PacketResponder * for block * terminating</td>
</tr>
<tr>
<td>Event4</td>
<td>Received block * of size * from *</td>
</tr>
<tr>
<td>Event5</td>
<td>BLOCKx NameSystem addBlocked: blockMap updated: * It is added to * size *</td>
</tr>
<tr>
<td>Event6</td>
<td>Verification succeeded for *</td>
</tr>
</tbody>
</table>

Structured Logs

<table>
<thead>
<tr>
<th></th>
<th>Event1</th>
<th>Event2</th>
<th>Event3</th>
<th>Event4</th>
<th>Event5</th>
<th>Event6</th>
</tr>
</thead>
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<td>BR_304791815403999562 Event5</td>
<td>BR_304791815403999562 Event6</td>
</tr>
</tbody>
</table>
Publications (1)


Thanks!

Q&A