PrefMiner: Mining User’s Preferences for Intelligent Mobile Notification Management

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Notifications Inform Users About a Variety of Events

Communication

Online Social Networks

System, Tools and Others
Are All Notifications Useful?
Are All Notifications Useful?

NO

Users are not interested in many notifications they receive and feel annoyed on receiving them.
Interruptibility Management System: State-of-the-art

Predict opportune moments by using:

- context of the user.
- content of notification.

Limitation

No past study has considered stopping or detecting notifications that are not useful for the user.
Interruptibility Management System: State-of-the-art

Evaluated in the offline settings.

Limitation

Never evaluated in the real-world scenario.
Contributions

1. A mechanism for learning the types of information users prefer to receive via notifications in different situations.

2. A technique to make the predictive model transparent to users.
Mining User Preferences
Mining User Preferences

- Removing Reminder Notifications
- Notification Clustering
- Constructing Association Rules
Mining User Preferences

- Removing Reminder Notifications
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S1: Removing Reminder Notifications

Some notifications are dismissed because they do not require any further action from the user.

\[
\text{Click Rate} = \frac{\text{Number of accepted notifications}}{\text{Total number of notifications}} \times 100
\]

If an application’s click rate is zero then all notifications from that application are treated as reminder notifications.
Mining User Preferences

- Removing Reminder Notifications
- Notification Clustering
- Constructing Association Rules
S2: Notification Clustering

1. Cleaning Notification Titles
   • Conversion of the text to lower-case
   • Removal of punctuation, numbers and stop words
   • Removal of the sender and application names
   • Stemming of words

2. Clustering Notifications
   • Removing sparse terms
   • Term Frequency-based clustering
S2: Notification Clustering

Removing sparse terms

\[ \text{TF}_{\text{threshold}} = \frac{\text{Number of participation days}}{N \times \text{Total number of notifications}} \]

This ensures that at least one notification containing the term is triggered in \( N \) days.

Not much difference in the number of filtered terms with \( N \in [2, 7] \).

We use \( N = 2 \) for \( \text{TF}_{\text{threshold}} \).
Mining User Preferences

Removing Reminder Notifications

Notification Clustering

Constructing Association Rules
S3: Constructing Association Rules

*We use the AIS algorithm for mining association rules.*

\[ X \rightarrow Y \]

\(X\) is the antecedent (never contains notification response)

\(Y\) as the consequent (only contains notification response)
S3: Constructing Association Rules

*We use the AIS algorithm for mining association rules.*

\[ X \rightarrow Y \]

\(X\) is the antecedent (never contains notification response)
\(Y\) as the consequent (only contains notification response)

**Support:**

\[
\frac{\text{Number of notifications of the notification-type covered in the rule}}{\text{Total number of notifications in the dataset}} \times 100
\]

**Confidence:**

\[
\frac{\text{Occurrence count of the notification pattern covered in the rule}}{\text{Occurrence count of the notification pattern covered in the antecedent of rule}} \times 100
\]
S3: Constructing Association Rules

We use the AIS algorithm for mining association rules.

\[ X \rightarrow Y \]

\( X \) is the antecedent (never contains notification response)
\( Y \) as the consequent (only contains notification response)

Let us consider an example where the user:

- always dismiss N1 notifications.
- does not accept N2 notifications at work.

\{N1\} \rightarrow \{Dismiss\}
\{N2,Home\} \rightarrow \{Accept\}
\{N2,Other\} \rightarrow \{Accept\}
\{N2,Work\} \rightarrow \{Dismiss\}
1. Evaluate (offline) the proposed intelligent notification mechanism.

2. Funnel the findings in an intelligent notification library: MyPref.

3. Implement an app on top of MyPref and deploy it to evaluate the library in a real-world scenario.
Evaluation (Offline)
Dataset

Study: My Phone and Me

Participants: 18

Minimum active days: 14

Notification samples: 11,185

Types of Association Rules

Assoc Rule 1: notification response with notification type.

Assoc Rule 2: notification response with notification type and activity.

Assoc Rule 3: notification response with notification type and arrival time.

Assoc Rule 4: notification response with notification type and location.

Assoc Rule 5: notification response with notification type, activity, arrival time and location.
Results

**Minimum Confidence:** 65-95%

**Minimum Support:** $D_{participate} / (2 \times N_{count})$

- $D_{participate}$: Days of participation
- $N_{count}$: number of notifications collected for a user

This ensures that the type of notification covered in each rule has arrived at least once in two days.

**Recall:** ratio between the number of notifications that are correctly predicted as dismissed and the total number of notifications that are actually dismissed.

**Precision:** ratio between the number of notifications that are correctly predicted as dismissed and the total number of notifications that are predicted as dismissed.
Recall: ratio between the number of notifications that are correctly predicted as dismissed and the total number of notifications that are actually dismissed.

Precision: ratio between the number of notifications that are correctly predicted as dismissed and the total number of notifications that are predicted as dismissed.
Recall: ratio between the number of notifications that are correctly predicted as dismissed and the total number of notifications that are actually dismissed.

Precision: ratio between the number of notifications that are correctly predicted as dismissed and the total number of notifications that are predicted as dismissed.
User’s preference for receiving a notification depends only on the type of information it contains and the location.

**Recall**: ratio between the number of notifications that are correctly predicted as dismissed and the total number of notifications that are actually dismissed.

**Precision**: ratio between the number of notifications that are correctly predicted as dismissed and the total number of notifications that are predicted as dismissed.
Optimizing the System for High Precision

- We should aim to have fewer false-negatives (i.e., incorrectly predicting a notification as non-interesting for the user).
- This can be achieved by ensuring that the precision remains close to 100%.
Optimizing the System for High Precision

90% precision
35% recall

• We should aim to have fewer false-negatives (i.e., incorrectly predicting a notification as non-interesting for the user).

• This can be achieved by ensuring that the precision remains close to 100%.
Online Learning
MyPref Library

An intelligent interruptibility management library that can predict the type of notifications that users would prefer to receive on their mobile phones in specific contexts.

Platform
Implemented for the Android OS.

Evaluation
It takes not more than 61 seconds for mining association rules from 1500 notifications for any features.

Released as an open source project
https://github.com/AbhinavMehrotra/PrefMiner
In-the-wild Evaluation
PrefMiner

PrefMiner allows you to create rules for stopping all unwanted notifications by alerting you. You can create separate rules for home and work place by enabling first it in settings.

2 Active Rules
1 Pending Rule

Do you want to activate these rules?

Stop notifications from Twitter that contains: 'suggestion' word(s) in the title.

Yes  Not now  Never

Stop notifications from Facebook that contains: 'candy', 'crush' word(s) in the title.

PrefMiner is filtering notifications by using the following rules.

Stop notifications from Play Store that contains: 'update' word(s) in the title.

On which app do you want to apply this rule?

Email
Facebook
Fit

Stop notifications that contain the words below.
Separated words by using commas.
candy, crush

Where do you want to use this rule?

All  Home  Work  Other

CREATE MY RULE
PrefMiner allows you to create rules for stopping all unwanted notifications from alerting you. You can create separate rules for home and work place by enabling first it in settings.

**Today's Results**

Filtered notifications: 0
Most disruptive app: ?
**Do you want to activate these rules?**

Stop notifications from Twitter that contains: 'suggestion' word(s) in the title.

- Yes
- Not now
- Never
PrefMiner is filtering notifications by using the following rules.

- Stop notifications from Facebook that contains: 'candy', 'crush' word(s) in the title.
- Stop notifications from Play Store that contains: 'update' word(s) in the title.
On which app do you want to apply this rule?
- Use it for all apps.

Email
Facebook
Fit
Email

Stop notifications that contain the words below. (Separated words by using commas.)
candy, crush

Where do you want to use this rule?
- All
- Home
- Work
- Other

CREATE MY RULE
In-the-wild Evaluation Results

Participants: 18

Duration: 15 days (minimum)

Data of 2 participants was not considered because they never accepted/dismissed any suggested rule.
Accepted Rules

Overall, 102 out of suggested 179 rules were accepted. 56.98% acceptance rate.
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70% (11 out of 16) users accepted 50% (and above) rules.
Filtered Notifications

Filter Recall = \( \frac{\text{N-Auto}}{\text{N-Auto} + \text{N-Manual}} \times 100 \)

N-Auto: Number of filtered notifications by the system
N-Manual: Number of notifications dismissed manually

Average filter recall for 16 users: 45.81%
PrefMiner: Exit Questionnaire

Triggered after 15 days

<table>
<thead>
<tr>
<th>Question</th>
<th>Average Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>I found the app useful for learning my preferences to filter notifications.</td>
<td>4.25</td>
</tr>
<tr>
<td>The app filtered most of the notifications that I didn’t want to receive.</td>
<td>4.33</td>
</tr>
<tr>
<td>The app incorrectly filtered notifications that I wanted to receive.</td>
<td>1.58</td>
</tr>
</tbody>
</table>

1:Strongly disagree - 5:Strongly agree
Take Aways

• First *in-the-wild* study for automatic extraction of rules that reflect user’s preferences.

• An open-source library (MyPref) that can learn the type of notifications that users would prefer to receive on their mobile phones in specific contexts.

• PrefMiner represents a very effective, yet transparent, solution for interruptibility management for mobile devices.
Questions?

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