Context-Aware Smartphone Application Category Recommender System with Modularized Bayesian Networks

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Abstract—The number of applications available since the late 2010’s, and the number of smartphone user sharply increasing. However, not all applications are not useful or helpful. In other words, to obtain satisfactory results in the search can be difficult means. Users to find what they want to search for a many times. To solve this problem, previous studies have proposed the use of recommender systems. Most of the system uses age, gender, preference based collaborative filtering. Collaborative filtering has the problem that data sparsity, cold-start or needs lots of users’ personal data. In this paper, we propose a smartphone context-aware application category recommendation. We use Bayesian-network to inference context and recommend the category when inference context and we have set the probability of using category from collected data. We tested our proposed system with F1 measure, accuracy of inference context.

Keywords- Mobile App recommendation, Recommendation System, Context-Awareness, Bayesian Network

I. INTRODUCTION

The wide spread of Smartphones has cataclysmically increment of Smartphone applications. Google’s android play store has over 700,000 applications since Oct, 2012 [1], there is an apparent information overload emerging in the domain of mobile applications. Because of this problem, several researchers have suggested recommendation systems to resolve this. Currently, there are a number of mobile application recommendation systems, but most of are not context-aware. One of that, AppBrain which serves as an application manager with the capabilities of providing personalized recommendations to its users [2]. In former services are using installed rate of another application or collaborative filtering based recommendation method, but these are derived from a simple install count or many other peoples' histories [3, 4]. If the system has not a massive-information about other peoples installed application info, it is not suitable current context adaptive application recommendation and user personalization [5].

In this paper, we infer user's context with Bayesian network and recommends Category of the application. In recent, utilize context in recommender system has gained popularity with Smartphones. Mobile smart devices could be used in varying contexts. Smartphones equipped with a rich set of embedded sensor to afford to infer appropriate contexts. Therefore, context in recommendation system needs to be understandable. Furthermore, recommending category is more reliable than user ratings. In mobile Smartphone application, each application has category provided by application developer which is pointing of its purpose. In context inferring, we compose the modular Bayesian network with inferring context from modularized user-state and user-activity, and merging the result of inferred, recommending category module.

We have tested our proposed system F1, nDCG measure for recommended result to show performance and accuracy to show inference context performance.

II. RELATED WORKS

A. Recommendation services

The recommending information method can be divided into two ways. Content-based recommendation analyzes recommended content itself or meta-data and find out user-preferences point and recommends closest content. On the other hand, collaborative filtering recommends contents which are picked out by similar users. This method will decrease the accuracy when the system does not have massive information from many users. Application recommendation recommends installing an app or necessary app among the uninstalled-app. So far, recommend method mainly used is popular apps by other people or similar user group of collaborative filtering.

Girardello et al [3], suggests application that AppAware which is a mobile application that captures and shares installations, updates, and removals of Android programs in real time. Accordingly, AppAware allows its users to see what applications are being installed right now or around their position by other people. Yan et al [4], present the AppJoy system that makes personalized application recommendations by analyzing how the user actually uses her installed applications. Based on all participants' application usage records, AppJoy employs an item-based collaborative filtering algorithm for individualized recommendations. And they discuss AppJoy's design and implementation. Song et al [6], offers collaborative filtering by other peoples application install ratio to use recommend
application. Böhmer et al [5], they present work in progress on a platform that gives rise to context-awareness for the mobile application recommendation. It records the users' application usage and relates it to context information that is trace on the users' devices.

And the research of movie genre recommendation as a category recommendation. Media such as movies or songs do have associated category information. This category information used to recommend. Category information is usually highly reliable because it is provided by experts. For instance genre/category of a movie is decided on by the movie’s director or producer. Moreover, this information is provided when the contents are made. Therefore, the system does not need to wait for information from users to be able to recommend applications--this feature handles the cold-start problem. Category information, is already available for content recommendation [7].

B. Context-aware recommendation

Table 1 summarizes the works to recommend using context of users. The early research which is providing appropriate context aware application or contents is actively running. Debnath et al. [8], propose a hybridization of collaborative filtering and content based recommendation system. Proposes to recommend user situation adaptive application and obtain feedback from users (preference-Good, bad) using to reflect the next recommendation and the changes goodness of fit. Yu et al [9], present an N× M-dimensional (N2M) recommendation model. The model considers context information—ranging from user preference and situation to the device and network capability as input for both content and presentation recommendations. Bellotti et al [10], presents a context-aware mobile recommender system, codenamed Magitti. Magitti is unique in that it infers user activity from the context and patterns of user behavior and, without its user having to issue a query, automatically generates recommendations for content matching. Bär et al [11], present a novel program automatically generates recommendations for content recommendation [7].

### TABLE 1. RECOMMENDATION WITH CONTEXT-AWARE

<table>
<thead>
<tr>
<th>Author</th>
<th>Context</th>
<th>Recommended Content</th>
<th>Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yu et al</td>
<td>Location, activity, time</td>
<td>Media</td>
<td>Web</td>
</tr>
<tr>
<td>Bellotti</td>
<td>Location, activity, time, weather, user, input</td>
<td>leisure</td>
<td>Smartphone</td>
</tr>
<tr>
<td>Kuo et al</td>
<td>Location</td>
<td>Hotel</td>
<td>Smartphone</td>
</tr>
<tr>
<td>Min et al</td>
<td>Location, activity, time, emotion, busyness, stress</td>
<td>Callee</td>
<td>Smartphone</td>
</tr>
</tbody>
</table>

The old method of Application recommendation uses just used before or fully learned of every application information. In this paper, we propose using category data which from App stores, but without comparing each user’s preference to recommending application category, and redirect the user to an Appstore recommended category section.

### III. PROPOSED SYSTEM

The old method of Application recommendation uses just used before or fully learned of every application information. In this paper, we propose using category data which from App stores, but without comparing each user’s preference to recommending application category, and redirect the user to an Appstore recommended category section.

To recommend user situation adaptive application category, this paper uses stance, location, time, date. First, location data use where if a user uses specific application category in a specific location, this location-category data have meaningful to recommend. Second, time and date data if a user uses specific application category in a specific time,
this time and date-category data have meaningful to recommend. Preprocess the given information from the device, refine to meaningful information, and gets the category which is best appropriate category in the current situation from infers with Bayesian network. Figure 2 is the overall process of the entire system.

A. Classified application category

To classify application category, we reference common application store’s classify data. Representative common application store is Apple’s app store and Google’s play store. Classification of application would use purpose, running type, using frequency, but common application store mostly uses purpose of application. Table 2 is the list of classified application category by purpose or function of the applications.

<table>
<thead>
<tr>
<th>Category</th>
<th>Example types of apps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communications</td>
<td>Messaging, chat/IM, dialers, address books, browsers, call management, etc.</td>
</tr>
<tr>
<td>Health &amp;Fitness</td>
<td>Personal fitness, workout tracking, diet and nutritional tips, health &amp;safety etc.</td>
</tr>
<tr>
<td>Medical</td>
<td>Drug &amp;clinical references, calculators, handbooks for healthcare providers, medical journals &amp;news, etc.</td>
</tr>
<tr>
<td>Media &amp;Video</td>
<td>Subscription movie services, remote controls, media/video players</td>
</tr>
<tr>
<td>News &amp;Magazines</td>
<td>Newspapers, news aggregators, magazines, blogging, etc.</td>
</tr>
<tr>
<td>Weather</td>
<td>Weather reports</td>
</tr>
<tr>
<td>Business</td>
<td>Document editor/reader, package tracking, remote desktop, email management, job search, etc.</td>
</tr>
<tr>
<td>Social</td>
<td>Social networking, check-in, blogging, etc.</td>
</tr>
<tr>
<td>Games</td>
<td>Sub Category: Arcade &amp;Action, Brain &amp;Puzzles, Cards &amp;Casino, Casual, Sports</td>
</tr>
<tr>
<td>Traffic</td>
<td>Traffic information</td>
</tr>
</tbody>
</table>

Category means a group which contains same properties, the best represent a keyword of the application. Recommends classified application category, make users to select an app in many apps of the category. For example, a user needs a “subway arrival notifies an app”, there is so many apps to provide subway information, but all of these in the “Traffic info” category. If the proposed system recommends “Traffic info” category, then the user could select the best appropriate app to the user.

B. Using sensor data from a smartphone

To recommend the most appropriate category, we define data which from the sensor. Users’ usability will decrease when if kept asking user’s input on Smartphone environment. Design the information based data that without the user’s repetitive or additional intervention and design Bayesian network. The sensors we use that are accelerometer, magnetic, gyroscope, light which are embedded in a Smartphone.

In addition, time data would be preprocess as 07 to 12 as morning, 12 to 13 as launch, 13 to 18 as afternoon, 18 to 19 as dinner, 19 to 24 as night. Date data separated by weekday and weekend. Preprocess of user state values would be more specific as lifestyle or job.

C. Inference user context and recommend category

To inference user context, we have designed a Bayesian network in modularized. First, to recognize the user’s situation like sitting, standing and lying, we use the accelerometer of a Smartphone with Bayesian network. Many former research says can distinguish activities by accelerometer [16-18] Bayesian network’s input uses discretized value [19]. Therefore, the data from accelerometer needs to be discretized. We separated data form accelerometer as same width. And construct Bayesian network structure and learning the parameter with a discretized accelerometer value. Structure of Bayesian network into a Tree structure to use in mobile environments, which has limited computing power [15]. Figure 2 is a Bayesian network to inferring stance. The parameter of Bayesian network is learned by EM algorithm and collected data by our collecting system in normal living status.

| Figure 2. STANCE REFERENCE MODULARIZED BAYESIAN NETWORK |

And second, inferred stance on user will be evidence of inferring user's context. Bayesian network which is inferring user context would designed by domain knowledge which from users general living pattern from Statistic Korea. As shown Figure 3, inference user stance is the input value of a context inference Bayesian network. This is the example un-modularized Bayesian network that in infers category.
And third, inference context would be an evidence of recommending category. Figure 4 is shown category inference Bayesian networks. Inferred context from Figure 3, which are exercise, meal, moving street, rest, shopping, sleep, study, stay public and view, would be evidence of inference category. Category recommending Bayesian network also designed by domain knowledge. And categorically recommend Bayesian network also would be modularized to tree structure by each category. As mentioned, while mobile environment limited computing power [15].

Following the Smartphone usage research on the actual condition report from Korea Internet & Security Agency. Which from the popular category apps rated that user’s use. Finally, the result of the third module of Bayesian network returns the probability of each category will user use. Table 3 shows the example result of recommendation.

<table>
<thead>
<tr>
<th>Category</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic</td>
<td>57.64</td>
</tr>
<tr>
<td>Communication</td>
<td>44.83</td>
</tr>
<tr>
<td>Health</td>
<td>66.05</td>
</tr>
<tr>
<td>Medical</td>
<td>54.22</td>
</tr>
<tr>
<td>Media</td>
<td>42.04</td>
</tr>
<tr>
<td>News</td>
<td>49.55</td>
</tr>
<tr>
<td>Weather</td>
<td>62.03</td>
</tr>
<tr>
<td>Business</td>
<td>39.48</td>
</tr>
<tr>
<td>Social</td>
<td>40.94</td>
</tr>
<tr>
<td>Games</td>
<td>58.66</td>
</tr>
</tbody>
</table>

And so we would recommend the category from higher order like Health, Weather and Games.

IV. EVALUATION AND EXPERIMENTATION

A. Evaluate by $F_1$

We set our recommend system to recommend the best 3 categories of user. A recommended category in this system would be highest ranked category, and could be evaluated inspect this result how many items succeeds recommended [21]. User answered given scenarios that a user will use recommended category in such circumstances in the item that recommended by the organization. $F_1$ is an indicator that is a harmonic mean of precision and recall. We did this experiment to 5 graduate students totally 100 times to use recommended.

B. Accuracy of inferring context

We also tested our context inferring with the modularized Bayesian network. We collected sensor data from Android Smartphone, with every half second. Totally 7257 sequences of data. Selected 200 data of each context, compared with real activity and inferred context. Figure 6 shown result that the average of the context inference is 82.95%
V. CONCLUSION

In this paper, we were proposing context-aware Smartphone application category recommendation and implemented android environment. Our proposed method tested by comparing rule-based category recommendation. And we inferred user's context with 9 situations and recommend category of 10 types. Out main task was to reflect context-aware and recommend category with context info. To context-aware, we use the rich set of sensors embedded Smartphone, and modularized Bayesian network to infer the user's context in limited computing power like mobile. Context-aware system have proven to be worth enhancement of the recommending systems, however the results are not very conclusive about usage of more various users and situation.

Future work involves that not only recommend category, but also each application, and we would like to also consider other approaches to enhance context-aware accuracy or application recommendation accuracy. And also need to consider energy efficient context-aware and recommendation.

REFERENCES


