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Levelized Recommendation Method in Internet of Things Environment

Joonhee Kwon[1] and Sungrim Kim[2]

[1]*Department of Computer Science, Kyonggi University, San 94-6, Yiui-dong, Yeongtong-ku, Suwon-si, Kyonggi-do, Korea*
[2]*Department of Internet Information, Seoil University, 49-3, Myonmok-dong, Jungrang-Ku, Seoul, Korea*
[1]*kwonjh@kyonggi.ac.kr*, [2]*srkim@seoil.ac.kr*

Abstract

The Internet of Things (IoT) is one of the most promising technologies for the changing the world. With the advent of IoT environment, new technologies are needed in recommendation methods. The existing recommendation methods provide recommendation using users and items, but they do not consider the characteristics of IoT. The recommendation methods need to incorporate IoT characteristics into it. This paper presents a levelized recommendation method in IoT environment. Our method integrates the traditional recommendation method with the social relationships between objects in IoT environment. The recommendation method is proposed, a scenario is described, and then several experiments are performed. The experimental results show that the proposed method's recommendation performance is better than other existing method in IoT environment.

Keywords: *Recommendation, Internet of Things, Social Network, Levelization*

1. Introduction

The Internet of Things (IoT) is the network of physical objects or "things" embedded with electronics, software, sensors, and network connectivity, which enables these objects to collect and exchange data [1]. The IoT links the objects of the real world with the virtual world, thus enabling anytime, anyplace connectivity for anything as well as for anyone [2-4].

Social Network Services(SNS) are increasingly drawing attention to academic and industry researchers. What makes SNS unique is that they have a relationship with friends [5]. People tend to trust the opinions of friends they know rather than the opinions of strangers [6]. Social recommendation method utilizes data regarding user's social relationships to filter relevant information to users, and predict the utility of items, users, or groups based on social environment of a given user.

It is needed for recommendation method to produce high quality recommendation quickly in IoT environment. However, there has been little research on it. Our method is a new recommendation method using social network in IoT environment. It integrates the traditional recommendation method with the social relationships between objects, using user's attention.

The paper is organized as follows. In Section 2, we provide a survey of related works. In Section 3, we present a levelized recommendation method and illustrate a music recommendation scenario. In Section 4 we evaluate the efficiency of levelized recommendation method. Finally, Section 5 will conclude the paper.

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2. Related Works

2.1. Recommendation Method

Recommendation methods apply knowledge discovery techniques to the problem of making personalized recommendations for information, products or services during a live interaction [7]. Collaborative filtering method is one of the most common techniques used in the recommendation method.

Collaborative filtering method searches for useful information appropriate for the user's characteristics, and then provides the relevant information to the user. It is categorized into two method, user-based collaborative filtering method and item-based collaborative filtering method. The core of the user-based collaborative method is to understand the relationship between users. Item-based collaborative filtering method measures the similarity between items, and then predicts the item preference for a particular user. There are a number of different ways to compute the similar between items [7].

The weighted sum method is widely used for calculating a prediction in item-based collaborative filtering method. It computes the prediction on an item *i* for a user *u* by computing the sum of the ratings given by the user on the items similar to *i*. Each rating is weighted by the corresponding similarity $S_{i,j}$ between items *i* and *j*. R means the preference of the user *u* of the item *j*. The prediction $P_{u,i}$ is computed as below [7].

$$P_{u,i} = \frac{\sum \text{all similar items, } N(S_{i,N} \; X \; R_{u,N})}{\sum \text{all similar items, } N(|S_{i,N}|)}$$

2.2. Internet of Things

IoT connects all things, that is people and things, things and things, things and systems. The information is created, collected, shared and utilized without user's intervention in IoT. It creates a new paradigm for context-aware, information processing, convergence of things and things, convergence of things and human beings.

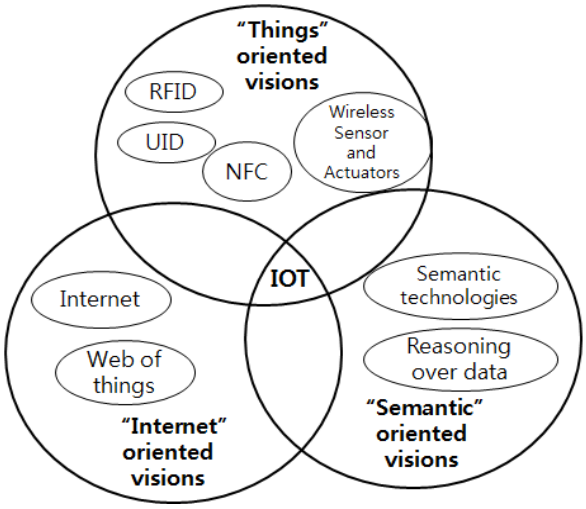


Figure 1. IoT: Three Main Visions

IoT can be seen as the result of the convergence of the three main visions, that is "Things"- oriented visions, "Internet"- oriented visions and "Semantic"- oriented visions. It is shown as Figure 1 [8].

2.3. Social Internet of Things

Social Internet of Things(SIoT) is the convergence of social network service and IoT [9-11]. Social network has the social relationships only between human beings. SIoT has social relationships between human beings and things, things and things, things and their owners.

The five social relationships in SIoT are defined as follows [11-12].

- Parental object relationship(POR): established among objects belonging to the same production batch
- Co-location object relationship(C-LOR): established among objects used always in the same place
- Co-work object relationship(C-WOR): established whenever objects collaborate to provide a common IoT application
- Ownership object relationship(OOR): established among heterogeneous objects which belong to the same user
- Social object relationship(SOR): established when objects come into contact, sporadically or continuously, because their owners come in touch with each other during their lives

Recently, a recommendation method using social relationships in IoT was proposed[13]. It proposes the SIoT prediction preference, SIoT_P. SIoT_P is composed of the prediction preference P and social relationship SR as follows:

$$SIoT\_P(i,j,k) = SR_{ij} \text{ X } P(owner_i, k_j)$$

$P(owner_i, k_j)$ is the preference prediction on an item k of an object j for an owner of an object i. It is based on weighted sum of the item-based collaborative filtering method. SR_{ij} is a social relationship weight between an object i and object j ($0 \leq SR_{ij} \leq 1$). It is calculated as follows:

$$SR_{ij} = SOR_{ij} \text{ X } CLOR_{ij} \text{ X } EOOR_{ij} \text{ X } POR_{ij}$$

3. Levelized Recommendation Method

3.1. Recommendation Method

In this section, we describe a levelized recommendation method in IoT environment. Our method makes a levelized recommendation differently according to a user's attention in consideration of social relationships between objects in IoT environment.

We propose a levelized preference prediction considering social network in IoT environment, LSIoT_P. The LSIoT_P consists of two factors. Firstly, the LSIoT_P adopts the preference prediction of the traditional recommendation method, item-based collaborative filtering [7]. However, the method does not guarantee good results in IoT environment, because it does not consider IoT environment. Secondly, to overcome the limitation of the traditional recommendation method, the LSIoT_P adopts social relationships between objects in IoT environment [11].

To recommend more relevant items in IoT environment, two above-mentioned factors are combined using a user's attention. When a user is not paying attention, items are recommended using the preference prediction. As the degree of attention increases, items

with social relationships between objects are recommended. In our levelizing scheme, the degree of attention is denoted by a level value. The higher the attention is, the higher the level value is.

Our preference prediction mechanism works as follows: *LSIoT_P(i,j,k,x)* computes the prediction in level value *x*, on an item *k* of an object *j* with a social relationship between an object *i* and *j*. $P(owner_i, k_j)$ is the preference prediction on an item *k* of an object *j* for an owner of an object *i*. For the prediction, weighted sum technique [7] is used. P_{max} is the maximum value of the preference prediction, P. SR_{ij} is a social relationship weight between an object *i* and object *j* ($0 \leq SR_{ij} \leq 1$). The social relationship weight, SR_{ij} is defined in [13]. It is possible to compute LSIoT_P using the following formula with a single adjustable parameter α_x ($0 \leq \alpha_x \leq 1$). As the level value *x* increases, α_x also increases.

$$LSIoT\_P(i, j, k, x) = \alpha_x \times SR_{ij} + (1-\alpha_x) \times \frac{P(owner_i, k_j)}{P_{max}} \quad (1)$$

Figure 2 shows the flow diagram of our recommendation method. The first step is to determine the level value from user's attention. The level value can be adjusted by the levelizing policy according to application characteristics. When the user just scans items without attention, the level value is determined as the low value and then our method performs like the traditional recommendation method.

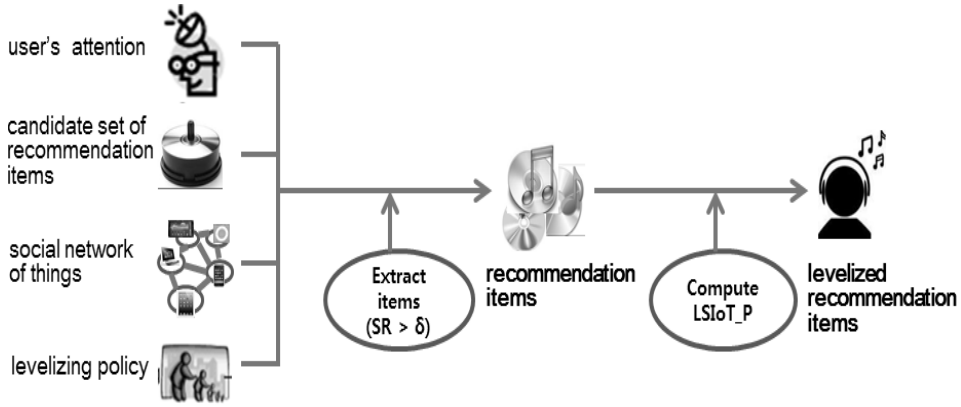


Figure 2. Flow Diagram of Levelized Recommendation Method in IoT Environment

Secondly, when the user pays attention to items, our method considers the social relationship weight, SR. When a user pays less attention to items, he or she gets only items of objects with higher SR. Now a user pays more attention to items and then, he or she needs to get items of objects with lower SR as well as them with higher SR. Using the observation, in the level with the low value, our method avoids unnecessary data access by eliminating items of objects with low SR. For each level value, our method extracts only items with SR above the threshold value, δ , not all items. It enables more rapid recommendation.

Finally, our method computes LSIoT_P. It is necessary to rank recommendation items extracted from the second step. By equation (1), LSIoT_P is computed for each recommendation items. Then, the items are ranked according to the LSIoT_P and then the items are recommended in descending order of LSIoT_P.

3.2. Scenario

This section presents a music recommendation scenario in IoT environment using our method. Lucy listens to music on her smartphone attached with the proposed method

through her bluetooth headset, while taking a break in her office. In this scenario, we compare the proposed method with the existing method by only the preference prediction.

The following are levelizing policy of the scenario. First, just listening to music is considered as no attention, so that level value is 1 and α_x in equation (1) is 0. Second, searching for music as well as listening to it is considered as a little attention, so that level value is 2, α_x is 0.3 and δ of SR is 0.3. Finally, when she listens to music for a long time in level with value 2, the level value is 3, α_x is 0.7 and δ of SR is 0.2.

Table 1 shows candidate set of recommendation items in this scenario. In Table 1, 'Music Title' is the name of an item, 'Owner' is the owner of device with the item, 'Genre' is the genre of the item, 'P' is the preference prediction on the item, and 'SR' is the social relationship weight between her device and the owner's device.

Table 1. Candidate Set of Recommendation Items

Music Title	Owner	Genre	P	SR
Honesty	Joshua	Soft rock	3.28	0.43
She's Gone	Joshua	Soft rock	2.96	0.43
Tears In Heaven	Joshua	Soft rock	2.51	0.43
Love Of My Life	David	Soft rock	2.81	0.31
You Mean Everything To Me	David	Soft rock	2.66	0.31
Love	John	Soft rock	3.59	0.22
I'll Be There	Joshua	R&B	2.78	0.43
Open Arms	John	Soft rock	3.14	0.22
Let It Be	David	R&B	3.84	0.31
Piano Man	John	Soft rock	2.48	0.22
Last Christmas	John	Dance	1.58	0.22
The Sound Of Silence	Kevin	Soft rock	3.95	0.11
Woman In Love	Kevin	Soft rock	3.77	0.11
Heaven	Kevin	Soft rock	3.19	0.11
How Deep Is Your Love	Kevin	R&B	2.97	0.11
Top Of The World	Kevin	R&B	1.49	0.11
Imagine	Julian	Soft rock	3.86	0.00
Bridge Over Troubled Water	Julian	Soft rock	3.26	0.00
Heal The World	Julian	Soft rock	2.32	0.00
Dancing Queen	Julian	Dance	2.43	0.00

Suppose that she just listens to music while surfing the web. According to our levelizing policy, the level value becomes 1. In this level, our method considers only the P like the existing method, because α_x is 0. Both the existing method and the proposed method show the same result as shown in Table 2. We can show that 'The Sound of Silence' with the highest P value is top recommended music. This scenario assumes that items of Julian's mobile device in candidate items are excluded because of bluetooth compatibility problem between Lucy's smartphone and Julian's mobile device. For the above reason, SR values of the items are also zero in Table 1.

Table 2. Recommendation Items: Level 1

Music Title	Owner	Genre	P
The Sound of Silence	Kevin	Soft rock	3.95
Let It Be	David	R&B	3.84
Woman In Love	Kevin	Soft rock	3.77
Love	John	Soft rock	3.59
Honesty	Joshua	Soft rock	3.28

Heaven	Kevin	Soft rock	3.19
Open Arms	John	Soft rock	3.14
How Deep Is Your Love	Kevin	R&B	2.97
She's Gone	Joshua	Soft rock	2.96
Love Of My Life	David	Soft rock	2.81
I'll Be There	Joshua	R&B	2.78
You Mean Everything to Me	David	Soft rock	2.66
Tears In Heaven	Joshua	Soft rock	2.51
Piano Man	John	Soft rock	2.48
Last Christmas	John	Dance	1.58
Top Of The World	Kevin	R&B	1.49

Now, she finds cool music and then searches for music by genre, 'Soft rock'. So the level value becomes 2. In this level, the result of the proposed method is different from it of the existing method. We can observe that top recommended music, 'The Sound of Silence' in the Table 3 is not shown in the Table 4. The music has a high P value, but has a very low SR value, 0.11. The proposed method considers the social relationship weight, SR, as well as P, because she pays attention to music. In this level, it extracts only items with SR above the threshold value, 0.3, not all items. It results that the top recommended music in the existing method is not shown in the proposed method.

Table 3. Recommendation Items (Existing Method) : Level 2, Level 3

Music Title	Owner	Genre	P
The Sound Of Silence	Kevin	Soft rock	3.95
Woman In Love	Kevin	Soft rock	3.77
Love	John	Soft rock	3.59
Honesty	Joshua	Soft rock	3.28
Heaven	Kevin	Soft rock	3.19
Open Arms	John	Soft rock	3.14
She's Gone	Joshua	Soft rock	2.96
Love Of My Life	David	Soft rock	2.81
You Mean Everything To Me	David	Soft rock	2.66
Tears In Heaven	Joshua	Soft rock	2.51
Piano Man	John	Soft rock	2.48

Table 4. Recommendation Items (Proposed Method) : Level 2

Music Title	Owner	Genre	P	SR	LSIoT_P
Honesty	Joshua	Soft rock	3.28	0.43	0.5867
She's Gone	Joshua	Soft rock	2.96	0.43	0.5419
Love Of My Life	David	Soft rock	2.81	0.31	0.4864
Tears In Heaven	Joshua	Soft rock	2.51	0.43	0.4789
You Mean Everything To Me	David	Soft rock	2.66	0.31	0.4654

She listens to music for a long time in level with value 2, and then the level value is changed to 3. Unlike Table 4, Table 5 shows that items of John's mobile device are recommended. Because, the proposed method in level 3 extracts items with SR above lower threshold value, 0.2, as compared with the threshold value of SR in level 2.

In addition to it, unlike Table 4, the music "Tears In Heaven" is ranked higher than music "Love Of My Life" in Table 5. We can see SR value of the former is higher than it of the latter. The most influential factor of LSIoT_P in the level 3 is SR, not P. It makes the results different.

Table 5. Recommendation Items (Proposed Method) : Level 3

Music Title	Owner	Genre	P	SR	LSIoT_P
Honesty	Joshua	Soft rock	3.28	0.43	0.4943
She's Gone	Joshua	Soft rock	2.96	0.43	0.4481
Love	John	Soft rock	3.59	0.22	0.3856
Piano Man	John	Soft rock	2.48	0.22	0.3659
Tears In Heaven	Joshua	Soft rock	2.51	0.43	0.3389
You Mean Everything To Me	David	Soft rock	2.66	0.31	0.3105
Open Arms	John	Soft rock	3.14	0.22	0.2997
Love Of My Life	David	Soft rock	2.81	0.31	0.2649

4. Experiments

4.1. Experimental Setup

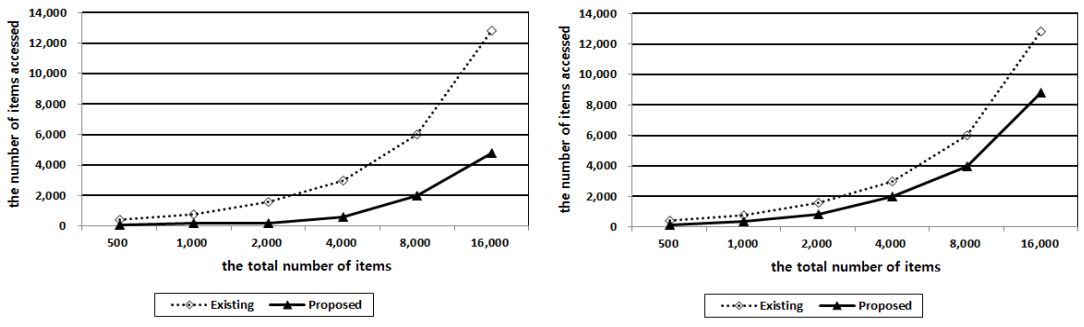
This section presents experimental evaluations of our method. We implemented both the existing method and the proposed method. All programs were written in Java.

We generated 6 different data sets varying the total number of items from 500 to 16,000 with an increment of two times. The preference prediction value, P, for each item is generated randomly. The number of devices is set to 20 and the social relationship weight for each device is generated randomly from 0 to 1.

In IoT environment, disconnection between devices can be occurred many times because of mobile environment and compatibility problem, etc. For example, in section 3.2, Lucy's smartphone and Julian's mobile device is disconnected because of bluetooth compatibility problem. Considering this IoT environment characteristic, the device's disconnection rate is set from 0.1 to 0.3.

The number of levels in the generated data is set to 3. For LSIoT_P computation, the following adjustable parameters are set. When level value is 1, α_x is set to 0. When level value is 2, α_x is set to 0.3 and δ of SR is set to 0.5. When the level value is 3, α_x is set to 0.7 and δ of SR is set to 0.2.

4.2. Experimental Results



(a) Level 2 (b) Level 3

Figure 3. The Number of Items Accessed

We evaluated the efficiency of levelized recommendation method. We measured the number of items accessed whenever the number of total items is increased. Figure 3 shows the result of performance by varying the number of items for each level. It does not show the result in level 1. When level value is 1, α_x is set to 0, so that the both existing method and proposed method show the same result. That is why this experiment is performed only in level 2 and level 3. In Figure 3, the existing method is called "Existing" and the proposed method is called "Proposed".

Several observations are found in Figure 3. First, the number of items accessed of the proposed method is consistently smaller than it of the existing method. Second, as the total number of items is increased, the difference between performance of the proposed method and the existing method increases. Figure 3(a) and Figure 3(b) show the experimental results for each level. Figure 3(a) shows greater performance difference than it of Figure 3(b). This is due to the fact that when the level value is low, the proposed method avoids accessing items of devices with low SR.

From the experimental evaluation, we discover that our method is rapider than the existing method as the number of items increases. Moreover, when the level value is low, our method shows better performance than the existing method.

5. Conclusion

With the advent of IoT environment, new technologies are needed in recommendation methods. The traditional recommendation methods do not make good results in IoT environment, because they do not consider the characteristics of IoT. We proposed a new levelized recommendation method in IoT environment.

In IoT environment, social relationship among objects can be constructed in analogy with the social relationship of human beings. Our method integrates the traditional recommendation method with the social relationships between objects in IoT environment. It uses a user's attention to integrate two factors. As the degree of attention increases, the social relationship is considered unlike the traditional recommendation method.

This paper presented a levelized preference prediction mechanism and flow considering the social relationship in IoT environment. Then, we explained our method with a music scenario. Several experiments were performed and the experimental results showed that our method had a good performance.

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Authors

Joonhee Kwon, she received her B.S., M.S. and Ph.D. in Computer Science from Sookmyung Women's University, Korea in 1992, 1994, and 2002, respectively. She worked for Ssangyong Information & Communication Corporation, Korea from 1994 to 2003. She is a Professor in Department of Computer Science, Kyonggi University, Korea. Her research interests are Database, Information Retrieval, Social Network, Internet of Things, and Mobile Computing.

Sungrim Kim, she received her B.S., M.S. and Ph.D. in Computer Science from Sookmyung Women's University, Korea in 1994, 1997, and 2002, respectively. She is an associate professor in Department of Internet Information, Seoil University, Korea. Her research interests are Database, Information Retrieval, Social Network, Internet of Things, and Mobile Computing.