Recommender system for Users of Internet of Things (IOT)

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Summary
The evolution of Information Technology caused a new concept called "Internet of Things" (IOT) wherein some devices meet user needs in the form of online manner. Servers that are provided by some companies control each of these devices and users select IOT objects based on their requirements. The main aim of this paper is to studying the recommendation system for IOT devices that are beneficial for users based on their preferences. Thus, we propose a recommendation system that works based on created graph between users, objects, and services, recommending an appropriate IOT device to customers based on their needs and interests. In addition, users and services characteristics are considered in this research study to recommend the best option to users. Results contend that the precision of proposed algorithm is higher than current ones.

Keywords
Recommender system, Internet of Things, IOT, services

1. Introduction

The revolution of Information Technology and intelligent systems serve as a breeding ground for adventing the new concept called "Internet of Things". IoT contains some devices that are working under specific protocol, using Internet as a communication tool [1]. The IOT consists of various tiny and smart gadgets with fluctuating working frameworks, CPU, memory, and etc. Additionally, these devices can be utilized remotely in the field where individuals' intervention or design is unbelievable [2]. As an example, numerous kinds of smart phones, electricity controller, heat measuring devices, and various kinds of sensors, which have processor and internal memory turned into smart devices. Researchers have estimated that the number of these gadgets will increase to 212 billion in 2020 [3]. Eventually, the aim of IOT is an exchanging and updating the information and consequently, achieving desirable performance for whole system [4]. For instance, different technologies such as Radio Frequency Identification (RFID), Near Field Communication (NFC), Machine-to-Machine (M2M) and Vehicular-to-Vehicular communication (V2V) offering special services to customers based on their needs [5]. These items are assembled with microcontrollers, transceivers to enable interaction, configuring with protocol stacks, which will recognize the transaction of the objects with one another to reach to common purpose without individual interference [6]. In this regard, by proliferation of IOT gadgets and services, choosing appropriate services based on users requirements has become a colossal debate because users usually cannot select a service, which is beneficial for them. Also, For assessing users regarding choosing suitable IOT services based on their daily needs, recommender systems are develop to help users' in their decisions [7]. Decision making is one of the inevitable parts of human life. Having a plenty of choices and the lack of adequate knowledge from decision space and lack of time, all leads decision making process difficult. Recommendation systems appear to solve these problems [8]. These systems are developing swiftly which are often in the form of software systems facilitating user decisions in many areas such as tourism, restaurant and so forth [9]. Recommendation systems work based on statistical and knowledge discovery techniques in order to recommend items to users [10]. The performance

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of these systems is based on user preferences and behaviors and in the next level, the outcomes of recommendation systems are options that are suitable with each user favorites, helping them to select the best options among their choices [11]. In terms of analyzing user's information there are a three key factors including user, object, and service and the relationship between them is triple which means that each user uses some devices that each one belongs to specific companies. In this regard, clients come across with numerous options that recommendation system would help them regarding finding a suitable choices. In this study we consider user profiles similarity and devices were used by users to recommend the best IOT devices to them. Actually, the similarity of user profiles makes recommender system offers options to users precisely in order to use IoT devices.

2. Literature review

Recommendation systems play an essential role in various fields and IOT is no exception. In recent years the IOT technology utilized recommender systems to optimize offered options to IOT users, analyzing devices data and user behaviors [12]. Recommendation systems divided into two major groups including Content Based Filtering and Collaborative Filtering. Content Based Filtering find user interests based on similar items to those that a user liked in a past. This filtering system relies on user behavior and ranked items. Items characteristics has studied and the item with the most similarity with the user behavior is nominated as a interesting item for user for recommending to him/his in the next level [13][14]. In Collaborative Filtering, interests and mutual preferences are recognized then, the rating are compared to each other with the use of appropriate likeness approach to propose a suggestion items to users [15][16]. The influence of IOT on human's life is inevitable, getting more and more popular among people in urban areas. In IOT, everything can be used as an IOT device by unique IP address [17]. In fact, all devices can interact and process the data, which is transfer amongst them [18]. In addition, the success rate of this technology is highly related to the defined standards, which should be enabling to propose interoperability, compatibility, high reliability, and effective performance. International Telecommunication Union suggests five layers for IOT architecture consists of; sensing, accessing, networking, middleware, and application layer [19]. In this regard, Shah and Yaghoob conducted a review research regarding Internet of Thing (IOT) and its applications and obstacles. They studied four related technologies to IOT such as; RFID, NFC, M2M, and V2V. Each of these technologies has pros and cons and is used based on specific function. For instance, smart car parking, data collection, smart repository of water, smart house and office and so forth. Also, the main disadvantages of IOT are security issues, accessibility and reliability [5] [20]. Another study focused on the use of big data on IOT. In essence, IOT creates a great bulk of data. The big data analysis is needed to take advantages of its potential for high-level modeling and knowledge engineering. So, that offers enhancement analytic method and a concept that makes machine usage easier and effective [21]. In paper [22], researchers proposed a recommender system based on neural networks to recommend options to IOT users. These suggestions included Gas stations, Restaurants, and Tourist spots. Neural network started to recognize user behavior then, GPS suggested a range of options to users. For example, when the fuel of user car going to be finished, the system recommends the nearest fuel station to user. The results of this study presented that the accuracy of recommendation system is roughly 98 percent [22]. Moreover, another study designed a recommender system, which is worked based on IOT, recommended options to users in smart phones. In fact, the proposed system recommended items to buy through smart phone. Results of this study could improve e-commerce in order to sell IOT devices [23]. In addition, in paper [24], researchers analyzed and evaluated some recommendation algorithms for IOT users. As an example, the most popular devices were recommended to users. Hence, the authors proposed an Internet of Things Service Recommendation (IOTSRS) algorithm and compared this algorithm to similar one. The results indicated that the performance of IOTSRS algorithm is more efficient than other similar algorithms [24].

3. Proposed framework

The framework of our model is depicted in below figure:

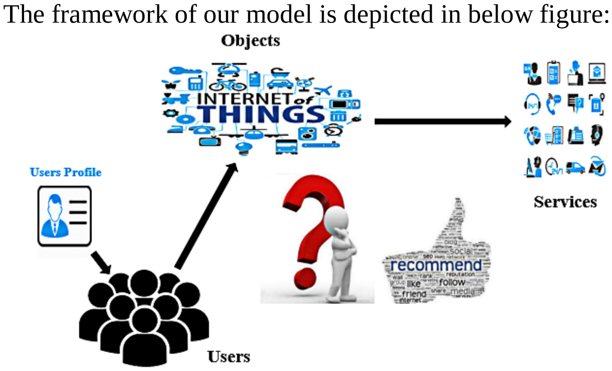

Figure 1. The IOT architecture based on users, services, and devices

As it can be seen in figure 1, the architecture of proposed framework consists of three major parts including users, services, and devices. This framework contains some users that each of them has particular profile, using IOT devices and these devices supported by some servers in the companies. Thus, each service comprises some IOT objects and users utilize these objects. The recommender system analyzes users information based on three factors (user, services, and device) and recommend appropriate options to them, assisting them in order to use other IOT devices.

4. Methodology

In the first level, the proposed recommendation system starts to analyze user behavior which is include the information of using IOT stuffs next, the system find the similarity of users behaviors and finally, recommend IOT objects to users based on their profile similarity. Defined relationships between three major factors (user, service, device) in the framework are explained in the next part.

4.1 Defined relationship between three major factors

In IOT, the relationship between users, objects, and services can be defined as a triple graph (figure 1). The parts of this graph are divided into three sections as below;

$U = \{ U_1 , U_2 , U_3 , \ldots. U_n\}$ that include "n" users.

$O = \{ O_1 , O_2 , O_3 , \ldots. O_m\}$ that include the objects which are used by clients and $S=\{S1, S_2, S_3,\ldots.S_k\}$ that contains the number of firms that offer variety of services to IOT users. Accordingly, X defines as users of IOT devices;

$X \subseteq \{u, o, s: u \in U, o \in O, s \in S\}$ (1)

Where X is a member of all three components so that we can find the similarity between X and other three factors.

In the first state, the relationship between objects and services calculated as below;

$OS (o, s) = |\{x=u, o, s \in X: u \in U\}|$ (2)

The relationship between users and services defines as below;

$US (u, s) = |\{x=u, o, s \in X: o \in O\}|$ (3)

The correlation between users and objects is presented as below;

$UO (u, o) = |\{x=u, o, s \in X: s \in S\}|$ (4)

And the correlation between two users based on common objects and services define as below;

$U_1 U_2 (s, o) = |\{x=u, o, s \in X: u_1 u_2 \in U\}|$ (5)

According to defined relationship between items, we can analyze all three elements to recommend options to users. The ranges of recommendation options are explained in the next section.

4.2 Variety of recommendation options to IOT users

According to previous defined relationship between elements, in this section we consider various suggestions to users.

B.1 Internet of Things Popularity Service (IOTPS)

The service, which is used frequently by users, will be recommended to other users as formula 6 in below [26].

$S (u, o)=\mathrm{Argmax} (|Xs|)$ (6)

$s \in S$

B.2 Internet Of Things Popularity Objects (IOTPT)

The IOT devices, which are used commonly by users, will be recommended to other users as formula 7 in below;

$O (u, s) = \mathrm{Argmax} (|Xo|)$ (7)

$o \in O$

B.3 Internet Of Things Services Recommender Systems (IOTSRS)

In this level, the services that are similar to user profiles will be recommended to users. Formula 8 describes as a below;

$U (o, s) = \sum_{u_1 ,u_2 \in U} \mathrm{sim}\, (U_1 , U_2) \times r_{u_1 , u_2}$

(8)$u \in U$

The similarity between U_1 and U_2 calculated based on profile items sim(C,C'). The more likeness between use U_1 and U_2 the more impact on coefficient and formula on user end electing

B.4 Proposed recommender System

Common ranked items among users should be identified in our recommender system hence, we use The Pearson correlation coefficient formula because experimental results from previous researches showed that Pearson correlation is better that Cosine likeness in terms of accuracy [11][25][26]. Therefore, in this study we apply Pearson formula as below;

$$\mathrm{Simi}_{i,j} = \frac{\sum m \in (i \cap j)\, (r_{i,m} - \acute{r}_i)(r_{j,m} - \acute{r}_j)}{\sqrt{m \in \sum_{(i \cap j)} (r_{i,m} - \acute{r}_i)^2}\sqrt{m \in \sum_{(i \cap j)} (r_{j,m} - \acute{r}_j)^2}} \quad (9)$$

Where $\mathrm{Simi}_{i,j}$ represents a distance of two items or users. If i and j are two users, then $i \cap j$ represent all items that these two users have ranked them. r_i and r_j are average ranked of user i and j on the same items $i \cap j$. $r_{i,m}$ is user I ranked to item m and $r_{j,m}$ is user j ranked to item m.

5. Experimental results

In this section, we evaluate the method for recommending to IOT users. There are two levels regarding this evaluation;

5.1 Dataset

For assessing the performance of proposed method we need to access a comprehensive database to analyze the data. Unfortunately, this kind of dataset is not available due to the limited use of IOT devices. To tackle this barrier in this study, we gathered the data from IOT users similar to data collection mentioned in paper [24]. Thus, the process of data collection has carried out by gathering the data from companies like Telus, Libelium, and BlueRover that provides IOT services to customers. 110 services and 160 IOT objects are explored to offer them to the customers in order to find out that which one is beneficial in customer viewpoint; which device they prefer to use regularly; and which device they are using currently? In this survey, 1875 respondent were get involved and they profiles were registered as well, including some information about their age, gender, and occupation.

6. Evaluation

The proposed algorithms are evaluated to explore the precision of recommender system. In this section, some similar algorithms compare to proposed algorithms; IoTPS and IoTPT that are presented in paper [24]. For assessing the precision of algorithms we use four measurement factors are used include; Precision, Recall, F-measure, and Root of the mean Square Error (RMSE). Using these measurements lead to estimate user behaviors precisely.

6.1 Precision

The Precision function formula defines as below;

$$\text{Precision} = \frac{|A|}{|A+C|} \qquad (10)$$

Where A represents the number of records that recommender system predicted them correctly and C indicates the number of records that are not chosen in A domain [11][27][28]. Results of applying these measurement elements are shown in figure 2 as below

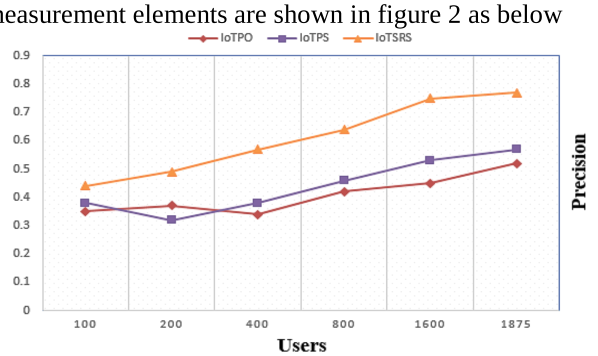

Figure 2. Algorithms evaluation by Precision measurement

The outcomes of Precision function indicate that the minimum amount of precision belongs to recommending popular devices and the second lowest point is dedicated to the most popular services. Consequently, the highest precision belongs to algorithm that recommend based on user profile similarity.

6.2 Recall

This measurement is a portion of relevant instances that have been retrieved over total relevant instances [11][27][28]. Equation 11 defines the Recall fraction.

$$\text{Recall} = \frac{|A|}{|A+B|} \qquad (11)$$

A refers to a records that recommender system estimated them correctly and B represents records that are not selected in datasets. Results presents in figure 3.

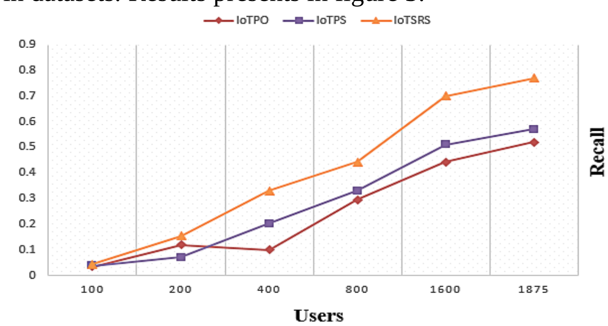

Figure 3. Algorithms evaluation by Recall measurement

As it can be seen in figure above, the maximum precision belongs to IOTSRS algorithm.

6.3 F-measure

This measurement defines based on Precision and Recall function [28][29][30], explaining as below;

$$\text{F1} = \frac{2.\ \text{Precision}\ .\ \text{Recall}}{\text{Precision} + \text{Recall}} \quad (12)$$

Results of applying F-measure function are sown in below figure 4;

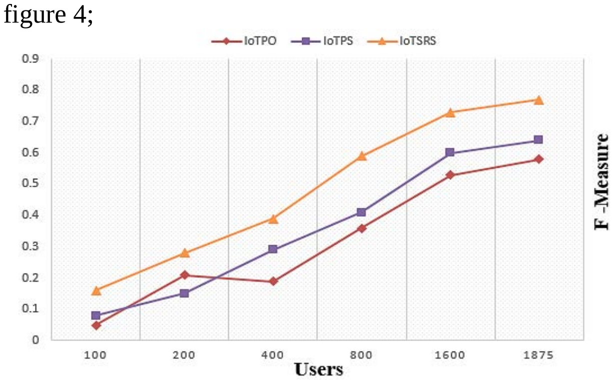

Figure 4. Algorithms evaluation by F- Measure measurement

As it is shown in figure 4, the maximum rate of precision is dedicated to IOTSRS algorithm. Actually, one of the most important points regarding evaluating of algorithms precision is that there is a relationship between increasing users and rising recommender system's precision. Therefore, our proposed algorithm performs efficiently in compare with other algorithms especially when the users increased.

6.4 RMSE

Is one of the common methods for identifying recommendation systems miscalculation, defining as a below equation [27][29][30];

$$\text{RMSE} = \sqrt{\frac{\sum (i,j)_{\in k} (i,j) \in k \ \ (p_{i,j} - v_{i,j})^2}{N}} \quad (13)$$

Where $p_{i,j}$ represents the estimation of ranking on j items by user I and $v_{i,j}$ represents real ranking of user i on item j. Also, N indicates the entire ranked items by users and $K=\{(i, j)\}$ exemplifies items and user rankings on them [11][30]. Results of RMSE measurement depicted in below figure 5.

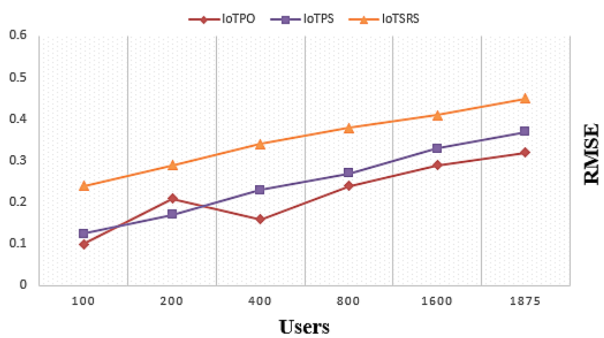

Figure 5. Algorithms evaluation by RMSE measurement

According to the figure 5, the precision of IOTSRS algorithm is higher than other two algorithms. Hence, proposed algorithm performs effectively.

7. Conclusion

In this paper, recommendation systems in IOT devices are studied and datasets of some firms such as Telus, Libelium, BlueRover that provide IOT services to customers is gathered. Based on survey that distributed among 1875 users, customer's interest factors have been collected and in the next level our recommender system suggest options to users based on popular devices (IOTPO), popular services (IOTPS), and profile similarity (IOTSRS). According to evaluation factors, Results show that minimum precision belongs to recommending popular devices. Hence, it indicated that although there are a various kinds of IOT things, this recommendation approach is not appropriate for UOT device users. In addition, the precision of recommender system in case of suggesting popular services is higher than previous method. This is due to the fact that popular services themselves offer several IOT objects that users tend to use these devices then, it leads to popularity of these devices among clients and also might breeding as a ground for behavioral similarity in users. In an ideal situation, the maximum precision related to recommending services to customers based on their profile similarities. In essence, user profiles play a significant role in their interests and users with similar profiles have same preferences regarding choosing services therefore, this solution would be beneficial for using IOT devices and analyzing user preferences based on their profiles. Furthermore, by growing the number of users, the accuracy of recommender system increases as well. Consequently, the performance of proposed recommender system is effective especially in a great volume of data and it is an important tools to analyze IOT users.

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