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SEM-PPA: A semantical pattern and preference-aware service mining method for personalized point of interest recommendation

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ABSTRACT

Point-of-Interest (POI) recommendation has received increasing attention in Location-based Social Networks (LBSNs). It involves user behavior analysis, movement pattern model and trajectory sequence prediction, in order to recommend personalized services to target user. Existing POI recommendation methods are confronted with three problems: (1) they only consider the location information of users' check-ins, which causes data sparsity; (2) they fail to consider the order of users' visited locations, which is valuable to reflect the interest or preference of users; (3) users cannot be recommended the suitable services when they move into the new place. To address the above issues, we propose a semantical pattern and preference-aware service mining method called SEM-PPA to make full use of the semantic information of locations for personalized POI recommendation. In SEM-PPA, we firstly propose a novel algorithm to classify the locations into different types for location identification; then we construct the user model for each user from four aspects, which are location trajectory, semantic trajectory, location popularity and user familiarity; in addition, a potential friends discovery algorithm based on movement pattern is proposed. Finally, we conduct extensive experiments to evaluate the recommendation accuracy and recommendation effectiveness on two real-life datasets from GeoLife and Beijing POI. Experimental results show that SEM-PPA can achieve better recommendation performance in particular for sparse data and recommendation accuracy in comparison with other methods.

1. Introduction

Location-based Social Networks (LBSNs), such as Foursquare, Facebook Place, Twitter and Jie Pang, combine online social networks and physical localization by using "check-in" to achieve the sharing and propagation of location-based services. Recent years, lots of sensor-embedded devices have been successfully applied to location monitoring to promote the development of LBSNs. Thereinto, smart phones are the most popular devices for getting online. Owners of smart phones can access Internet and use location-based applications ubiquitously to experience different kinds of services, such as multimedia entertainment (Xu et al., 2014a, 2015a,b), real-time news (Xu et al., 2014b) and traffic information (Gisdakis et al., 2015), etc. In that case, large numbers of the Internet services have been pushed to the subscribers with a variety of choices. However, the interested information of users is always submerged by many spam text messages, which causes users give up using the corresponding services. Thus, the challenge for future service recommendation systems is not to suggest more services "*to anyone, at anytime, from anywhere*", but recommending "*the suitable service, at the suitable time, in the suitable place, to the suitable person*".

Different from Web search engine, the service of recommendation systems not only concerns on the relationship among search results, but also considers the effect of users' personalized preference on different services. Traditional service recommendation methods include collaborative filtering (CF) (Cao et al., 2013; Zheng et al., 2011) and content-based recommendation (CBR) (Blake and Nowlan, 2007; Chen et al., 2011), which mainly rely on the 2-tuple information of "user-item". However, as the number of personalized demands increasing, only utilizing the relationship between user and service cannot exactly recommend the quality-aware services to users (Xu et al., 2013a). So the context information (e.g. time, location, social, environment, emotion and network bandwidth, etc.) must be taken into account to form the 3-tuple information of "user-context-item" when users request services. By making use of the 3-tuple information, context-aware recommendation system (CARS) (Khalid et al., 2014; Song et al., 2016) can provide the automatic and personalized selection to users in accordance with the variation context information.

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Point of Interest (POI) recommendation is a new type of service recommendation task that comes along with LBSNs. Similar to CARS, POI recommendation concerns on recommending personalized and quality of experience (QoE)-guaranteed services (Xu et al., 2013b) to the subscribers. Research topics covered in this area mainly include user behavior analysis, movement pattern model and trajectory sequence prediction, etc. Although the growing interest in POI recommendation has resulted in many solutions, there is still significant ongoing work to address the challenges as follows.

(1) *Data sparsity*: Users usually do not want to share their current locations with recommendation networks because of privacy issues. As a result, it is limited to recommend services only according to the location information in practical environment. Due to data sparsity, some existing location-based POI recommendation systems (e.g. Levandoski et al., 2012; Horozov et al., 2006; Ye et al., 2011) suffer a lot of difficulties by making use of the collaborative filtering model. Consequently, it cannot exactly recommend the suitable services for users to satisfy their personalized demands.
(2) *Location sequence*: Although users have visited the same POI in a geographical region, different location sequence often reflects the different preference of them (Xiao et al., 2014). Due to the lack of movement trajectory analysis, the similarity-based approaches fail to find out the suitable users with similar interest or preference, and in turn, deteriorate the quality of service via traditional POI recommendation algorithms.
(3) *New place*: Traditional POI recommendation methods lack the capability of recommending suitable services to users when they move into the new place (e.g. Adomavicius et al., 2005; Lian et al., 2014). In reality, one user absolutely owns his/her potential friends that live in new place with the similar interest or preference. Apparently, users can acquire the suitable services according to the movement trajectory of potential friends.

In summary, the traditional POI recommendation, which purely mines the user-location matrix, cannot sufficiently provide accurate and reliable predictions. Therefore, we propose a semantical pattern and preference-aware service mining method (SEM-PPA) for personalized POI recommendation in LBSNs. To overcome the first limitation described on data sparsity, we translate the geographical information into semantical information from raw Global Positioning System (GPS) trajectories. Also, we classify the locations into different types and identify the users in the same space, in order to find the similar users who own the different and sparsity location trajectory information. For the second limitation on location sequence, we construct a movement pattern model, which not only considers the different location sequence of users, but also involves the effect of user familiarity and location popularity. Furthermore, we provide a potential friends discovery algorithm to find the similar users with the same movement pattern. To evaluate SEM-PPA, we conduct a series of experiments based on two real-world datasets from GeoLife (Zheng et al., 2010b) and Beijing POI. The results show that SEM-PPA can provide a better recommendation performance than the other related approaches.

This study is a significant extension for our previous work (Zhu et al., 2016) by proposing a new personalized POI recommendation method, constructing the movement pattern model for each user, and conducting the extensive experiments for all new algorithms. The main contributions of this paper can be summarized as follows:

(1) We develop a SEM-PPA approach to tackle the personalized POI recommendation problem in LBSNs and propose a novel method to classify the locations into different types for location identification according to the geographical information and semantical information.
(2) We construct the user model for each user from four aspects, which are location trajectory, semantic trajectory, location popularity and user familiarity. In addition, a potential friends discovery algorithm based on movement pattern is proposed.
(3) We perform experiments on two real-life datasets from GeoLife and Beijing POI. Experimental results show that our SEM-PPA approach can achieve a better recommendation performance in particular for sparse data and recommendation accuracy by comparing with other methods.

The remainder of this paper is organized as follows. Section 2 discusses the related work. Section 3 provides the problem statement of our research. Sections 4 and 5 propose the algorithm for behavior detection model, and pattern and preference-aware service mining, respectively. Experiments and analysis are presented in Section 6, while Section 7 concludes the paper and gives future research directions.

2. Related work

In this section, we briefly review some related works on personalized POI recommendation, which mainly consists of user behavior analysis, movement pattern model and trajectory sequence prediction. The main objective of this paper is to propose a semantical pattern and preference-aware service mining method (SEM-PPA), in order to recommend the suitable POI-based services to satisfy the personalized demands of users.

2.1. User behavior analysis

It involves the research on user behavior analysis according to “check-in” information, which is an important process to reflect the interest or preference of users. Collaborative filtering is a typical method to analyze user behavior, Zheng et al. (2010a) made use of location features and activity–activity correlation to predict the possible activities of users. Noulas et al. (2012) predicted the next position for mobile users by analyzing the type, mobility flows and spatio-temporal characteristics of places. In order to recommend the personalized POI-based services, Griesner et al. (2015) proposed a fused matrix factorization by considering the geographical and temporal influences. A geographical probabilistic factor analysis framework was proposed by Liu et al. (2013) to explain the geographical influences on users' check-in behaviors. Zhang et al. (2015) proposed a personalized and efficient geographical location recommendation framework to personalize the geographical influences. Liu et al. (2015) proposed a general geographical probabilistic factor model to analyze the user mobility behaviors by taking various factors into consideration. What is more, according to the research of Song et al. (2015), it proved that the user movement behaviors could be influenced by social relationship. Huang et al. (2015) proposed a semi-supervised probabilistic model by integrating the personalized geographical influence and the social influence on individual user check-in behavior, in order to predict the probability that a given user visits a new POI. To cluster the similar users, Wang et al. (2014) proposed a multimode multi-attribute edge-centric co-clustering framework to discover the overlapping and hierarchical communities of LBSNs users. Although the aforementioned studies offer important insights into this topic, none of them worked on analyzing user behavior based on the semantic information and user preference. Our work aims to fill in this gap by modeling user movement behavior in a semantical space.