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Road-based travel recommendation using geo-tagged images

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ABSTRACT

Geotagged photos on social media like Flickr explicitly indicate the trajectories of tourists. They can be employed to reveal the tourists' preference on landmarks and routings of tourism. Most of existing works on routing searches are based on the trajectories of GPS-enabled devices' users. From a distinct point of view, we attempt to propose a novel approach in which the basic unit of routing is separate road segment instead of GPS trajectory segment. In this paper, we build a recommendation system that provides users with the most popular landmarks as well as the best travel routings between the landmarks. By using Flickr geotaggged photos, the top ranking travel destinations in a city can be identified and then the best travel routes between the popular travel destinations are recommended. We apply a spatial clustering method to identify the main travel landmarks and subsequently rank these landmarks. Using machine learning method, we calculate the tourism popularity of the road in terms of relevant parameters, e.g., the number of users and the number of Point-of-Interests. These popularity assessments are integrated into the routing recommendation system. The routing recommendation system takes into consideration both the popularity assessment and the length of the road. The best route recommended to the user minimizes the distance while including maximal tourism popularity. Experiments were conducted in two different scenarios. The empirical results show that the recommendation system is able to provide the user good travel planning including both top ranking landmarks and suitable routings in a city. Besides, the system offers user-generated semantic information for the recommended routes.

1. Introduction

Web 2.0 technologies enable users of social media to make contributions or to communicate with each other. Among the various types of information contributed and shared by users on social media, the geographic one is called Volunteered Geographic Information (VGI, Goodchild, 2007). The most common providers of VGI are Flickr, OpenStreetMap, Twitter, Facebook, YouTube, Wikimapia, Foursquare, etc. VGI has been used in research on tourism, disaster and crisis management, transportation, etc. As a typical photo-sharing provider, Flickr provides a platform where users can share their photos with metadata (e.g., size, time when photo was taken, location, camera type, etc.) and add textual information on the photos. Such textual information includes title, tag, etc. Georeferenced photos in Flickr are associated with locational, temporal and textual information, which reflect the behaviours and activities of users, particularly tourists. For instance, spatial distribution of Flickr images can reveal the underlying process of tourists' footprints. With a combination of spatial and the temporal dimensions, Flickr images can be used to uncover the trajectories and movements of tourists. From this point of view, Flickr can be employed to provide users with travel recommendations based on the identification of tourists' spatial and temporal patterns from images. In addition to the georeferenced photos, georeferenced posts in Twitter, geolocated check-ins in Foursquare, user-generated GPS trajectories, etc., have potentials of being leveraged for travel recommendations (Zheng, 2012).

From an insight into location-based social network (LBSN), Zheng and Zhou (2011) classify travel recommendations into two types: generic and personalized. Basically, a generic travel recommendation system should provide users the top ranked landmarks, travel sequences, and travel experts in a specified region (e.g., a city). In the contrast, a personalized system is able to provide an individual user with a distinctive recommendation based on the travel preferences and histories of the users (e.g., Cheng, Chen, Huang, Hsu, & Liao, 2011; Majid et al., 2012). Apart from the tourism attraction or landmark, routing is another important aspect of travel recommendation. GPS history data is often used to track the footprint of the user, which becomes an indicator of the user's trajectory and movement (e.g., Zheng, Zheng, Xie, & Yang, 2010). Representative or typical routings of tourists can be mined from huge amounts of tourists' trajectories and thus are recommended to the user (e.g., Lu, Wang, Yang, Pang, & Zhang, 2010). Some researchers take advantage of the trajectory similarity calculation to offer the

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individual user the most "similar" routing, which is acquired from the tracking histories of the other users, as the personalized routing (e.g., Cheng et al., 2011). To enhance the real-time usability of the travel recommendation application, time constraint is also taken into account in some research works (e.g., Lu et al., 2010).

In general, a good travel recommendation system should provide the user with the most interesting (popular) landmarks including routing paths as the most people recommended. Additionally, for tourists, an optimal routing should take into account not only the distance but also the tourism popularity. The research result of Popescu and Grefenstette (2009) shows that tourists normally do not take the shortest path between landmarks. Tourists usually like popular streets where they can glimpse more touristic attractions (e.g., churches, squares, statues, memorials, etc.) or satisfy some personalized needs (e.g., eating, shopping, mailing post card, etc.) before reaching their destinations. Thus, to measure the popularity of a road, not only the images taken of the road itself, but also the images taken of the Points-of-Interest (POIs) on or near the road should be taken into consideration. Moreover, in addition to the popularity of the road itself, POIs on or near the road should be taken into account to recommend the best routing. However, the previous research works generate recommended routings from the historic trajectories (or trajectory segments) of users directly. Unlike these previous research works, we have an alternative perspective on the routing generation, according to which a recommended routing is composed by a set of separate roads (or road segments) which are connected in road network. Therefore, the advantage of our approach is that we are able to consider the tourism popularity of road as a new feature of road's popularity in a routing planning problem, and based on the values of features including road popularity as well as other attributes (e.g., POIs), we are able to find out the best road set constituting the best overall routing.

In this paper, we propose a road-based travel recommendation paradigm combining the landmarks and the routing. The travel landmark can be identified by the georeferenced images with a spatial clustering method. The best routings between the travel landmarks are recommended to users in terms of calculating the total value of the defined recommendation index. This defined recommendation index is constituted by the popularity and distance of the road as well as number of the POIs. Section 2 reviews related work on travel recommendation using georeferenced photos. Section 3 introduces the proposed approach to recommending travel. Section 4 presents the experimental results and analysis. At last, the paper makes a conclusion and presents future work.

2. Related works

In tourism research, the leverage of geotagged images and GPS history data mostly focuses on hotspot and landmark identification, trajectory and movement mining as well as trip recommendation. The related research works on these aspects are introduced in the following sub-sections.

2.1. Hotspot and landmark identification

Through geotagged images, Kennedy, Naaman, Ahern, Nair, and Rattenbury (2007) firstly used spatial clustering method to recognize the landmarks, and then employed a location-driven approach to generate representative tags for these landmarks. Rattenbury, Good, and Maaman (2007) proposed an approach to extract place semantics from Flickr tags automatically. Comparative results showed that the proposed scale-structure identification (SCI) outperforms the baseline methods. Following this, Rattenbury and Naaman (2009) developed a new approach called TagMaps to extract semantic information of place, and compared it with the previous methods. The results showed that TagMaps method outperformed the existing ones. Using Flickr, Girardin, Dal Fiore, Ratti, and Blat (2007) identified local regions of tourist concentration in terms of the point density of tourists. Subsequently, based on the most active regions obtained by spatial data clustering, Girardin, Calabrese, Dal Fiore, Ratti, and Blat (2008) presented the spatial and temporal distribution of tourists during their trips to Rome. In addition, Girardin, Vaccari, Gerber, and Ratti (2009) measured the attractiveness of POI in terms of the presence of photographer. Crandall, Backstrom, Huttenlocher, and Kleinberg (2009) employed a non-parametric clustering method named *mean shift* to discover the significant landmarks at a global level and evaluated their method within several specific cities.

To mine interesting locations and classical travel sequences in a geospatial region, Zheng, Xie, and Ma (2009) proposed a HITS (Hypertext Induced Topic Search)-based model to infer a user's travel experiences and the interest of a location considering the relationship between user and location. The results showed that there existed a mutual reinforcement relationship between location interest and user travel experiences. Meanwhile, employing both users' travel experiences and location interests, they achieved the best performance of detecting the classical travel sequences Jankowski, Andrienko, Andrienko, and Kisilevich (2010) presented a geovisual analytic approach to discover people's preferenceson landmarks from Flickr photos. Their results could help to distinguish between sites that are occasionally popular among the tourists and sites already known as city landmarks. Moreover, Ji, Gao, Zhong, Yao, and Tian (2011) applied a spectral clustering method to identify landmark region and mined representative photos.

In this work, we employ DBSCAN method to identify the landmarks. It is a classic and popular density-based clustering method, which has several generalized forms, e.g. GDBSCAN and ST-GDBSCAN. Compared to the most of clustering methods we mentioned above, DBSCAN can identify the clusters of arbitrary shape without the specification of cluster count *a priori*. However, two parameters are required in DBSCAN procedure which might influence the clustering result. Unfortunately, there is not yet perfectly general method to search the optimal parameters which is adaptive to different applications. Therefore, we firstly generate different results of clustering at different values of the parameters. We subsequently compare these results and finally find out an appropriate pair of parameters. Among the clusters generated with this pair of parameters, we have three steps to distinguish the clusters resulted from landmarks with the ones resulted from some events or other things which are unrelated to tourism. Consequently, the identification of landmark will be enhanced.

2.2. Trajectory and movement mining

For pedestrian navigation based on mobile devices, Hile et al. (2008) proposed a system for the automatic generation of navigational instructions from collections of geotagged photos. The instructions consist of a sequence of landmark images augmented with directional instructions. Using geotagged photos, Andrienko, Andrienko, Bak, Kisilevich, and Keim (2009) built a flow map showing aggregated moves of photographers between different places. Defining some criteria to calculate the duration of the tourist's visit from Flickr photos, Popescu and Grefenstette (2009) exploited temporal information associated with touristic sites. Also, to extract trip-related information, Popescu, Grefenstette, and Moëllic (2009) characterized the discovered trips and computed the visit times of the sites. Aiming at solving the problem of automatic travel route planning, Lu et al. (2010) provided a customized trip plan enabling tourists to specify personal preference such as visiting location, visiting time/season, time duration of travel, and destina-

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