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The Evolution of Research on Multimedia Travel Guide Search and Recommender Systems

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Abstract. The importance of multimedia travel guide search and recommender systems has led to a substantial amount of research spanning different computer science and information system disciplines in recent years. The five core research streams we identify here incorporate a few multimedia computing and information retrieval problems that relate to the alternative perspectives of algorithm design for optimizing search/recommendation quality and different methodological paradigms to assess system performance at large scale. They include (1) query analysis, (2) diversification based on different criteria, (3) ranking and reranking, (4) personalization and (5) evaluation. Based on a comprehensive discussion and analysis of these streams, this survey evaluates the recent major contributions to theoretical and system development, and makes some predictions about the road that lies ahead for multimedia computing and information retrieval (IR) researchers in both academia and industry world.

Keywords: Geo-Multimedia, Travel Guide systems, Recommendation, Information Retrieval, Survey.

1 Introduction

With the rapid growth of Internet, various online communication and sharing services have emerged as major communication channels for different kinds of users for different purposes. In particular, User-Generated Content (UGC) on social multimedia platforms has been significantly changing the way people understanding travel destination and the users increasingly reply on a large variety of geo-multimedia prior to finalizing the travel plan [25,41,14]. The geo-multimedia information includes not only the scenes and activities along with landmarks, but also travelers' context information, such as the number of tourist in group, the budgets, time and traveling schedules etc.

Multimedia travel guide system aims to effectively search or recommend a list of landmarks which could assist the users to plan travel and the abstract

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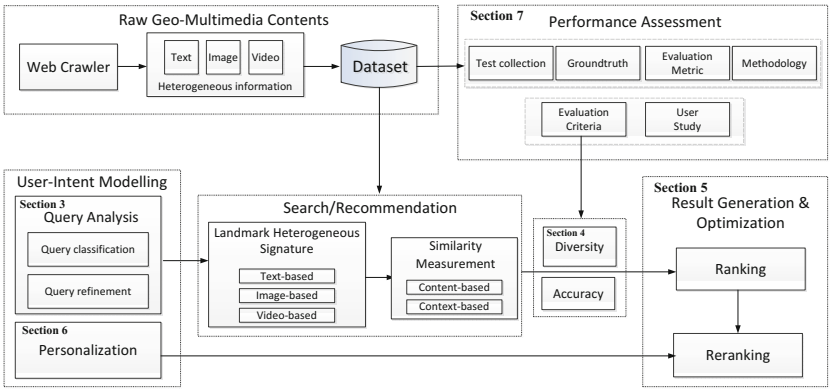

Fig. 1. The framework of travel guide systems

view of the general system architecture is illustrated in Figure 1. The system collects and analyzes information of landmarks from various online resources and ranks the landmarks based on their characteristics, as well as users' needs, preferences and current contextual information. The landmarks are characterized using heterogeneous representations to facilitate users to browse and search. In general, the system harvests geo-multimedia data online and stores the data in database. When a search query is submitted, the system calculates the relevance of each landmark with respect to the query using ranking/reranking algorithm. The query may be refined via classification or expansion. The search results are sorted in the descending order based on the relevance. In order to achieve comprehensive summary, collecting and analyzing different aspects about landmarks, such as histories, visual appearance and associated social activities or events effectively becomes a critical issue. In presentation of the retrieval results, each landmark is described by detailed textual descriptions as well as representative visual views. Further, different types of landmarks can be grouped into various clusters to facilitate fast browsing. Further, to assess the performance of a travel guide system, test collection, query set, as well as ground truth for the query set are essential. The performance of the system is evaluated by assessing the search results of all queries in the query set based on evaluation metrics, such as precision.

Developing travel guide search system is difficult. One of the key challenges is complexity and heterogeneity of online geo-multimedia. In general, they can be treated as a nonlinear composite of various kinds of contents from different sources. Applying the solutions developed for the extraction of knowledge from traditional multimedia solely might be not feasible and effective. Another problem is how to present the search and recommendation results to users so that they can quickly obtain comprehensive information about different types of landmarks. This problem is highly related to the diversification and visualization of the search results. Besides, users' queries are based on short text and thus they are not always specific and accurate. In order to capture users' intents concisely,

it is important to develop an intelligent scheme to reformulate and refine the query. Moreover, users have their own travel preferences and behavior patterns. Even for the same user, the requirements may be changed dynamically under different contexts. Consequently, developing intelligent algorithm to incorporate users' context and personal preferences into design of ranking/reranking scheme becomes crucial. And a subsequential question is about how to construct users' personal profiles.

This survey reviews different aspects of multimedia travel guide search and recommendation systems in a detailed way. In Section 2, we give a detailed overview on multimedia travel guide search/recommender system and introduce a few typical systems in the domain. We present a summary of query analysis in Section 3. In Section 4, we present works done on diversity. Next, Section 5 presents the research related on ranking and reranking to list must-see attractions which can balance accuracy and diversity. In Section 6, we discuss and review the role and importance of personalization. Further, Section 7 provides overview of how to assess the system performance. In Section 8, we conclude by discussing several important issues for future study.

2 Overview

In recent years, multimedia travel guide search and recommendation system has became an important tool to assist people plan travel and understand various destinations. As a result, numerous systems have been developed, by leveraging rich online multimedia resources. This section aims to give a brief introduction to a series of representative travel guide systems. Figure 2 gives a clear overview on how the travel guide and recommendation systems evolve during the past decade.

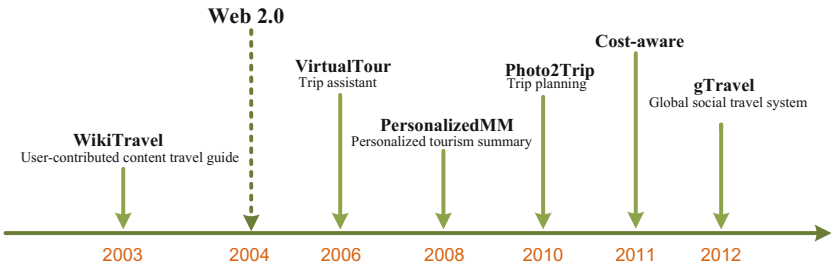

Fig. 2. The evolution of travel guide systems

To the best of our knowledge, WikiTravel [1] was the first travel guide portal, which aims to provide users timely and reliable information about landmarks. More recently, Web 2.0 sites have emerged as popular channel to allow users to interact with each other via social media. These online media sharing portals

(e.g., Flickr and YouTube) typically host a large volume of accessible travel-related information, which have been widely used by travel guide systems. VirtualTour [23] is an online travel service, aiming to provide high quality images to help travelers plan their trip with the collected images from famous photo forum sites. A user interface is designed to support search based on map, location or path. By analyzing over 110,000 geo-referenced photos collected from Flickr, DiverseSearch diversifies the search results to visualize different aspects of landmarks [25]. PersonalizedMM generates personalized landmark summary with respect to a user query, by utilizing texts, geo-tagged images and videos collected from Wikipedia, Flickr, Youtube, and tourism websites [37]. W2Go recommends the top landmarks of a targeted city by ranking, with the use of photos and associated metadata from Flickr and user knowledge from Yahoo Travel Guide [13]. Representative views of the recommended landmarks are presented to users. Based on 20 million geo-tagged photos collected from Panoramio and 200,000 travelogues crawled from other websites, Photo2Trip explores the destinations and travel routes between destinations, and then makes trip planning for travelers [28]. gTravel is a global social travel system, which assists tourists in itinerary planning, tour navigation and travel knowledge sharing [43]. Besides, the system can monitor trip status and make automatic changes on itinerary, and enables users to easily explore others' experiences with its social interactive functionalities.

Table 1 gives a comprehensive summary about key characterisitics of various travel guide systems and compares the systems from different aspects. From the perspective of utilized information sources, most systems use multiple modality information. To better describe a landmark or a trip for users, the textual description and visual representation are necessary. Social information is only applied by the most recent system. We expect that more systems will leverage the social information in future, as social relationships increasingly play an important role in personalized recommendation, and attract more and more attentions in other recommendation services. Additionally, we can observe that the latest systems start to consider diversity and reranking, which will be described in subsequent sections.

Table 1. Comprehensive comparisons of current travel guide systems. "S" and "R" in the "Type" column denote "Search" and "Recommendation", respectively.

System	Type	Multi-modality	Diversity	Relevance	Reranking	Personalization
VirtualTour [23]	S*	N	N	Y	Y	Y
DiverseSearch [25]	S	Y	Y	Y	N	N
PersonalizedMM [37]	R*	Y	N	Y	N	Y
W2Go [13]	R	Y	N	N	Y	N
Photo2Trip [28]	R	Y	Y	Y	Y	Y
gTravel [43]	R	N	Y	Y	Y	N

3 Query Analysis

Query analysis is one of the most important components for modern IR systems. To enhance the effectiveness of search, various kinds of algorithms/schemes have been developed to reformulate the query in recent years. When searching for travel destinations or landmarks, users don't have a very clear description about target and thus queries are generally abstract concepts (such as "leisure place") with a set of constraints, such as *distance*(e.g., near to some place) or a *geo-location range*(e.g. a city or a district). Sanderson et al. [32] reported that one fifth of queries are geographical, in which 80% queries were associated with geographical terms. Jones et al. [24] found that users tend to search for locations which were relatively close to their current locations. And the distributions of distances between the search location and current location of different query topics varied greatly by query topics. Besides, around 10% of query reformulations related to locations involve a geocorrection. These studies reflect the importance of geo-information in users' travel related queries. Thus, many researchers analyze and utilize geo information in user queries to improve the performance of various retrieval tasks. Andrade et al. [3] applied different strategies to combine the relatedness between two geographic places with textual ranking, and found out that geographic ranking can significantly improve results for some queries. Yu et al. [42] combined the thematic and geographic relevance measures on a per-query basis. Query specificity is used as a feature to determine the weights of different sources of ranking evidence for each query. Yi et al. [41] developed a city language model to analyze users' geo intent based on large amounts of web-search logs.

Analyzing query topics can be very helpful to refine the query at the topic-level, and achieve more accurate and diverse results. He et al. [19] showed that most multiple queries include more than one topic, and reported that most users reformulate query at the topical level. Fan et al. [11] proposed a method to expand the query based on topic distributions of the input query and the candidate terms. However, little work about query topic analysis has been done in travel guide search systems. How to detect the topics and refine the query accordingly is an interesting research topic, and should attract more attentions in the future. Besides, little effort has been devoted to multi-modality query (e.g. text, image and video) in travel guide systems. Multi-modality query is more natural and able to describe user information needs about landmark search in more comprehensive way. For example, when searching a landmark, which has certain visual or ambient sound characteristics, it is difficult for users to specify information needs using only one modality. Indeed, the reformulation of multi-modality query in travel guide systems is a new research direction and there are a lot of open issues.

4 Diversification

Multimedia travel guide search and recommendation systems are becoming increasingly important to individual users and business. However, while the majority of algorithms proposed in literature have focused on improving accuracy, an essential aspect - diversity, has often been overlooked. For very specific and clearly expressed queries, a returned result is simply judged whether it is relevant to the query or not. While for abstract query concepts or the queries with multiple topics, the diversity of the results becomes important. The diverse results increase the possibility for users to get the desired results. In travel guide systems, there are two types of diversity: (1) diversified representative views of a landmark; and (2) diversified landmarks - different types of landmarks. For the query with specific landmark, the information related to the landmark is returned. However, there are many different aspects of a landmark, such as the visual appearance and history. Even only for the visual appearance, there could be different to represent views. When searching for images of a landmark, users expect to see different views of the landmark to get a whole view of the landmark. For the query with no specific targets or recommendation systems, many different landmarks may satisfy users' requirements. Clustering landmarks into categories can facilitate the users to browse and discover the landmarks they prefer. On the other hand, even for the same landmark, different users may have different perspectives or be interested in different aspects of the landmark, such as some users are interested in the activities around the landmarks and others are more interested in the scenery. To meet the diverse needs of a wide variety of users, it is necessary to present diverse results to users.

In real world, each geo-landmark can be described and modelled using various kind of media information. Currently, most researchers focus on mining knowledge from heterogeneous information, such as travelogues, geo-photos and videos, to extract multiple attributes of a landmark. In [25], Kennedy et al. proposed a method to select diverse and representative landmark images by using tags and visual features. Mei et al. [29] presented a series of methods to discover latent semantic topics from blogs and their distributions over locations. Chen et al. [6] used time sequences of photos to identify the locations. Scenery and sightseeing qualities are considered in [46] to plan a travel route. Both textual and visual metadata are used to estimate the location of Flickr videos in [12]. Hao et al.[17] generated overviews for locations via analyzing representative tags from travelogues. Different characteristics of city landmarks are extracted from the blogs by exploiting graphic models in [21]. Snavely et al. [35] generated rich representations from images taken by different people at a single location. Simon et al. [34] solved the problem of scene summarization by selecting a set of images that efficiently represented the graphic content of a given scene. Crandall et al. [10] placed images on a map with the combination of textual and visual features, using a corpus of 20 million images crawled from Flickr. Recently, Rubinac et al. [31] created landmark summarization with diversified and illustrative photos of the places. Travel search systems [30] and [40] summarized landmarks with diverse visual content of photos for travel information retrieval. As shown above,

most of the recent researchers on diversity optimization focus on delivering a wide arrange of visual appearance for a targeted landmark, while little study has been done on using clustering to improve quality of end results. Further, very few existing studies consider to combine multiple modality (i.e. display results by using text, image and video) to diversify the result presentation. In addition, while achieving a good balance between search result diversification and effectiveness, no research has been carried out.

5 Ranking and Reranking

Users usually only pay attention to the top results in the returned list. Accordingly, ranking and reranking play key roles in all information search and recommendation systems. The main goal of ranking and reranking is to place the regarded most relevant results on the top, so as to maximize users' satisfaction and minimize the information load. Many reranking methods have been proposed, including the classification-based [39], clustering-based [20] and graph-based [36][47] methods. In travel guide systems, queries are usually accompanied with various constraints (e.g., distance constraints). On the other hand, there are heterogeneous information sources, such as text, image and video, associated with landmarks. Thus, in travel guide systems, ranking and reranking face different and more challenging problems, e.g., how to rank and rerank the results with respect to the constraints and these heterogeneous information.

Countless existing travel guide systems use only visual clues in ranking or reranking. By learning interested views from community photos, Ren et al. [30] created a table of content as a comprehensive summary of the landmarks via re-ranking the image search results. A DLMSearch system [40] is designed to support image query and diversify the landmark results through re-ranking to ensure the results to be highly pertinent, differ on landmark location and high visual quality. There are also systems which employ multiple information resources. Kennedy et al. [25] extracted representative views of a landmark by reranking Flickr photos using visual features based on the search results using tags. In [13], photos, user-generated reviews and ratings to Yahoo Travel Guide are combined together to generate the recommended landmarks. Reviews in Yahoo Travel Guide and image tags in Flickr are used to obtain preferences of users and determine the popularity of travel destinations. Based on user preference and travel site popularity, suitable popular places are selected for each user. Personalized travel recommendation system [9] uses locations and geo-tagged photos to rerank popular attractions.

As described, diversity is an important aspect of travel guide systems due to the intrinsic properties of travel related query. In existing systems, there are few systems considering the diversity in the design of ranking/reranking algorithms, such as [25] and [40]. More efforts should be invested into developing ranking/reranking algorithms in consideration of relevance and diversity simultaneously. This relates to the problem of how to quantitatively define the diversity of consequences, which is still an open question.

6 Personalization

With fast growth of geo-multimedia information in various social media portals, searching or recommending the contents associated with certain landmarks comprehensively becomes very tedious. To satisfy users' information needs accurately, personalization becomes one of the most essential enabling techniques to support different real life applications. For example, many users may prefer historic or cultural landmarks or travel sites, like a history museum, and some users could be interested in natural scenery. When recommending landmarks in a city, considering the preferences of users can better satisfy users' needs. Thus, intelligent personal travel guide system around the globe has created an urgent demand. As many applications have been successfully developed to enhance the quality of personal services. [37] designed a system in the multimedia view to generate personalized tourism summary in the form of text, image and video. In personal travel guide recommendation systems, users are recommended by travel routes. Xie et al. [38] proposed a method of composite recommendation of points of interest for tourists according to the tourist's budget. [28] focused on the relationships of many landmarks. Digital mobile devices are ubiquity, like mobile phone, digital cameras and tablet computer, which contain rich GPS positioning. Personalization in a mobile environment can provide more accurate and useful tourist recommendations which respect to personal preferences, usage, personal preference and other contextual information. [2] took advantages of contextual information to build prototypes of context-aware tour guide. This is one of the earliest applications to provide location-aware services in both indoor and outdoor. It also exploits user's historic locations to better assist the user. Personalized multimedia content with respect of users' preferences, location by mobile for sightseeing is studied in [33] to facilitate the individual decision. [5] presented an expert tourist guide called UbiquiTO, which adapts the provided content and user interests, as well as other context conditions like location and the device. [26] presented a system to estimate GPS for an image and [7] provided landmark identification with mobile devices. [22] can automatically generate a multimedia travelogue for mobile users. [16] utilized the compass in the mobile to give an intuitive way of information to the user in order to provide a tour guide. Averjanova et al. [4] developed a map-based mobile recommended system that provided personalized recommendations to users.

However, how to profile user's personal preference is a problem. Early personalized decision making systems asked users to input their preferences manually. [44] provides a study of exploiting online travel information to discover the interests of the tourists. Although some researchers tried to mine the personal preferences for personalized travel guide recommendation [44,15], they did not take into account contextual information in their approaches. Therefore, how to effectively mine users' preferences under different contexts from travel logs for personalized travel guide development needs to be further studied. Another interesting research direction is to explore the tourist travel graph, which contains the history of all tourists, to discover and utilize the relations or similarities between tourists for personalized travel recommendation. The upcoming field

studies shall analyze the behaviours and habits of all tourists, so that the system can use the tourist graph.

7 Performance Evaluation

In the context of multimedia travel guide search and recommendation systems [1], the evaluation is to assess whether the systems can be trustworthy and easy to use and results they provide can satisfy users' information needs. A reliable and robust evaluation methodology can provide quantitative and qualitative assessments to various systems. There are several limitations of existing evaluation methods: Test collection should contain data of numerous landmarks across the world. Besides, information for each landmark should be comprehensive with heterogeneous information. The baselines used in existing works are based on simple heuristic methods (e.g. *rank-by-count* or *rank-by-frequency*) or the results of commercial travel search/recommend engines (e.g. TripAdvisor and Yahoo Travel Guide). In existing works, to evaluate the developed systems, researchers construct their own datasets which contain the necessary information to support their research results, respectively, such as [13,8,18,13,45,27]. However, the self-constructed datasets cannot support cross method evaluation. The developed travel guide systems cannot be easily compared to each other.For the travel search/recommendation system, it is hard to give universal criteria for assessment. A reliable method is to assign each query with several assessors who are very familiar with the landmarks in the queried area (and who are also the corresponding type of people if it is required in the query); and then based on the majority vote principle to decide the ground truth. As mentioned before, the used ground truth is based on either the collected data or commercial travel search/recommend engines. There are two common objective evaluation methods, one is to use the results of existing travel engines (e.g., TripAdvisor [2]) as ground truth [18]; and another is to use a set of collected data as test set [13,8]. The evaluation methodology also plays an important role in the assessment of a system. When designing it, a few issues need to be considered and they include (1) which aspects of the systems are to be evaluated (e.g., robustness, effectiveness, efficiency, etc.); (2) for the evaluation of each aspect, what kinds of data and resources are required (e.g., queries, different datasets, participants in user study, etc.); (3) the evaluation metrics for the evaluation of each aspect; and (4) when comparing the proposed systems with other competitors, the arrangement of resources and sequence of steps should not affect the fairness of the comparison, such as the used queries and data for different systems, the sequence of using different systems in user study, etc. The principle is that the methodology should comprehensively evaluate the proposed system and fairly compare with other competitors. In addition, while user study is highly important to measure the performance of IR systems, very little existing research has investigated how to evaluate travel guide search and recommendation systems based on user study.

[1] Travel guide search/recommendation is actually a subdomain of IR research.
[2] `http://www.tripadvisor.com/Inspiration`

8 Conclusion and Future Research Directions

The availability of massive online geo-multimedia information is revolutionizing the way people search and recommend landmarks and travel destinations In this survey we present a comprehensive and timely review of state-of-the-art in the domain of the multimedia travel guide search and recommendation systems. The five key aspects related to the system development and algorithm design are identified and they include (1) query analysis, (2) diversification based on different criteria, (3) ranking and reranking, (4) personalization and (5) evaluation. Further, we provide a detail discussion and analysis of the latest technical developments in the five streams. More importantly, we hope that this article provides a clear roadmap for future research. As we have discussed, there is a wide range of promising research problems in this field. For example, one distinguishing characteristic for online geo-multimedia is multi-modality. In order to generate high quality recommendation and search results, how to effectively fuse different kinds of information is very crucial. Moreover, in recent years, with an explosive growth of social network services, popular websites such as Facebook and Twitter attract millions of users. Network and related user behavior analytics are especially suited for our field. User profiles often contain geographic information that can be very helpful to understand their travel activities. Some social networks like Foursquare [3] contain a large amount of users' check-in logs, which can be used to analyze user visiting pattern and user preferences. Besides, the social relationship between users can be analyzed based on the social network and leveraged for landmark recommendations. Thus, another important but challenging problem is how to leverage these valuable information.

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