Photo2Trip: An Interactive Trip Planning System Based on Geo-Tagged Photos*

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ABSTRACT
In this technical demonstration, we present a novel interactive trip planning system, i.e. Photo2Trip, by leveraging existing travel clues recovered from 20 million geo-tagged photos. Compared with the most common ways of trip planning, such as surveying travelogues and resorting to travel forums, Photo2Trip enables users to plan their trips in a more effective way. To meet users' diverse travel requirements, the system considers the following preferences: travel location (e.g. Beijing, Paris, or New York), travel duration (e.g. a two-day trip or a five-day trip), visiting time (e.g. summer, winter, March, or October), and travel style preference (e.g. prefer historic or prefer scenery sites). According to user requirements, Photo2Trip can automatically recommend popular travel routes among multiple destinations (attractions/ landmarks), and suggest typical internal paths within each destination. Moreover, users are allowed to interactively adjust the suggested plans by adding or removing destinations to get more customized travel routes from the system. Owning to 20 million geo-tagged photos and 200,000 travelogues, Photo2Trip is capable of supporting users plan travel routes for over 30,000 attractions/landmarks in more than 100 countries and territories.

Categories and Subject Descriptors
H.3.5 [**Information storage and retrieval**]: On-line Information Services – *Web-based services*

General Terms
Algorithm, Design, Experimentation

Keywords
Trip planning, Geo-tagged photos, Map interface

1. INTRODUCTION
The prosperity of tourism has made travel increasingly popular in people's everyday lives. With the rapid development of the Internet, more and more people share their travel experience on the web (such as writing travelogues or uploading photos taken at attractions) and resort to online help when they are planning a new trip. However, it is very time-consuming and inefficient for a user to find a proper travel route by manually summarizing tens of travelogues and find a proper travel route, as the information provided in travelogues is usually unstructured and varies from person to person. Therefore, an automatic and interactive travel route planning service is highly desired for users to plan a personalized trip.

Figure 1: The travel route recommended for Washington DC. Tourists can visit three attractions in the first day (the Lincoln Memorial → the White House → the Jefferson Memorial) and four attractions in the second day (the Commons → the Federal House → the Union Station → the Theodore Roosevelt Memorial).

Although GPS devices are widely available and can precisely record trajectories of users' trips, it is not easy to collect such trajectory data from numerous users due to their privacy concerns. Therefore it is generally impractical to use GPS trajectories for travel route planning in a worldwide scale. However, we have observed that, as the footprints of tourists at memorable destinations, the user-generated geo-tagged photos encode rich travel-related information. Moreover, these photos on the web are already publically available and sufficient to cover most countries and landmarks in the world. This motivates us to address the problem of trip planning by leveraging geo-tagged photos.

The most challenging problem we need to face is that tourists usually take photos at discrete positions and share only a small portion on the web. This makes photo-recorded paths usually sparse and incomplete, and therefore poses a great difficulty to travel planning. To address this problem, we propose to aggregate photos taken by multiple tourists at the same location, and deliberately design an algorithm [1] to recover as many as

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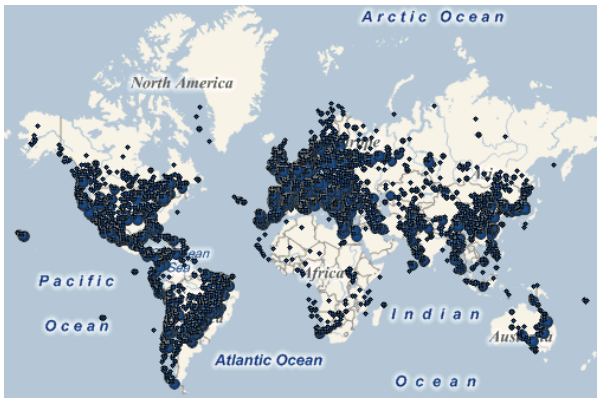

Figure 2: Discovered worldwide destinations using 20 million geo-tagged photos.

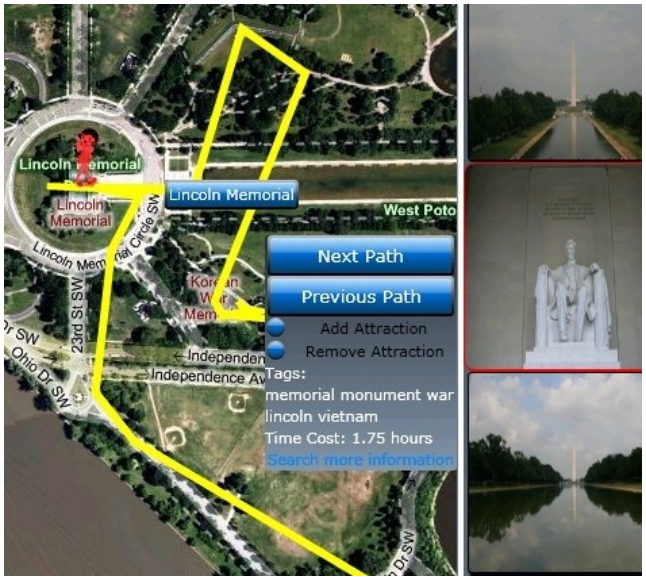

Figure 3: A typical path around the Lincoln Memorial. Representative pictures along this path are listed in the right panel. Informative tags about the attraction are listed to facilitate users to better know this attraction.

possible travel routes by merging incomplete travel paths from multiple tourists.

In this paper, we develop a real-time trip planning system, Photo2Trip. The system considers the following user preferences: travel location, travel duration, visiting time, and travel style preference. Fig. 1 illustrates a travel route automatically generated by the system for a two-day trip in Washington DC. Owning to 20 million geo-tagged photos from Panoramio (http://www.panoramio.com) and 200,000 travelogues crawled from Weblogs and professional travel websites, the system supports users to make trip plans for over 30,000 attractions/landmarks in more than 100 countries and territories. Fig. 2 shows the worldwide destination coverage of our system.

Besides the city level plans (i.e. the visiting order of different attractions), Photo2Trip also provides rich travel information at the attraction level (within an attraction). After clicking an attraction as shown in Fig. 1, the system will zoom to the attraction view and show an internal path, related tags and the

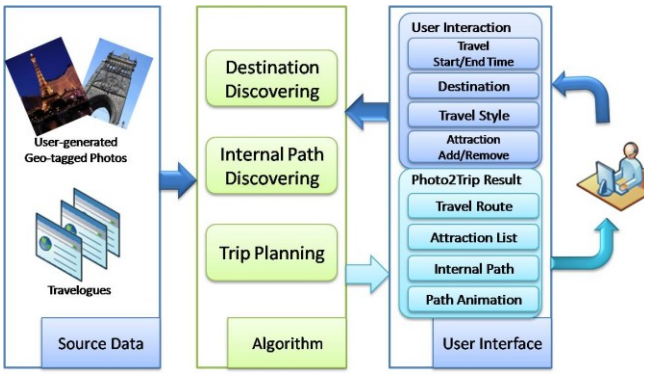

Figure 4: System pipeline of Photo2Trip.

time cost of this path, as illustrated in Fig. 3. There will be multiple internal paths within one attraction, with different time costs and representative pictures.

For example, a typical internal path recommended for "the Lincoln Memorial" is shown in Fig. 3. The right panel shows representative pictures along this path. By clicking a picture users can see the location of the picture on the map. After clicking the button "Animate the trip", an animation will be shown to users how the trip goes as well as the photos taken along this trip. Some descriptive tags are also provided to indicate the context of the Lincoln Memorial, including memorial, monument, war, Lincoln, and Vietnam. Referring to the photos and tags, users can determine whether an attraction meets their real needs. Under the tags there is a link button that allows users to get more information on the web. A user can remove or add any attraction along the recommended trip, and accordingly a new route will be automatically generated to meet the user's new requirements.

2. SYSTEM OVERVIEW

The framework of Photo2Trip is illustrated in Fig. 4. By leveraging a huge amount of geo-tagged photos and travelogues, three algorithms are developed to mine destinations, internal paths of attractions and travel routes among attractions. Users can specify the visiting time, visiting location, travel duration, and other preferences through the user interface and interact with the system by changing any of the input or adding/deleting suggested destinations in the trip plan. In the following subsections, we will briefly introduce these three algorithms. For details of the algorithms please refer to [1].

2.1 Destination Discovering

In order to generate travel routes for most popular locations in the world, our system first discovers popular destinations (i.e. attraction or landmarks) all over the world from 20 million geo-tagged photos crawled from web albums. Using the longitude and latitude as the feature of a photo, MeanShift Clustering Algorithm [2] is used to cluster the 20 million geo-tagged photos into over 300,000 clusters, from which the top 10% biggest clusters are preserved and considered as destinations. Each cluster is associated with its destination name according to a large gazetteer.

To generate customized trip plans, we associate each destination with users' potential preferences such as destination style and popular visiting time. Based on the 200, 000 textual travelogues crawled from the web, we mine the top style terms such as beach,

Figure 5: The interface of Photo2Trip. It contains four panels, i.e. Input Panel, Place Panel, Map Panel, and Image Panel.

historic site and bar for each destination as introduced in [3]. The best or popular visiting time of each destination is estimated according to the statistic information of related geo-tagged photos.

2.2 Internal Path Discovering

In real cases, a user usually takes photos at discrete positions along his/her travel path, out of which only a small part might be uploaded to web albums. Thus, geo-tagged photos uploaded by one user usually indicate incomplete footprints along his/her real travel path. Merging individual footprints together, we can obtain a more complete path.

We define path quality and path popularity to represent how ideal a path is, then merge footprints to candidate paths by leveraging path quality information, and finally rank these candidate paths to get the most representative ones.

We use the time span of all photos related to a merged path (after time calibration) as the discovered stay time of this path. Based on the statistical analysis of stay times, a stay time distribution can be obtained for each destination.

2.3 Trip Planning

We formulate the trip planning task as a graph analysis problem, which can be solved by a dynamic programming algorithm.

The destinations now correspond to the nodes V on the directed graph G(V; E), and the transition from one destination to another corresponds to the transition on the graph. Thus, the problem turns to be how to find the optimal path on the graph *G(V; E)*, along which the total score is maximized subject to the constraint that the total time cost is less than or equal to travel duration set by the user.

3. USER INTERACTION

Photo2Trip is capable of supporting users to make trip plans for over 30,000 attractions/landmarks in more than 100 countries and territories. To ensure that users are able to interactively adjust any part of the automatically suggested plans if they have any requirements that the suggested plans do not meet, the system provides the following functions:

1. A user can specify the visiting location, the start time and end time of his/her travel, and the travel style preference, based on which Photo2Trip could automatically recommend a trip plan with internal paths in each attraction.

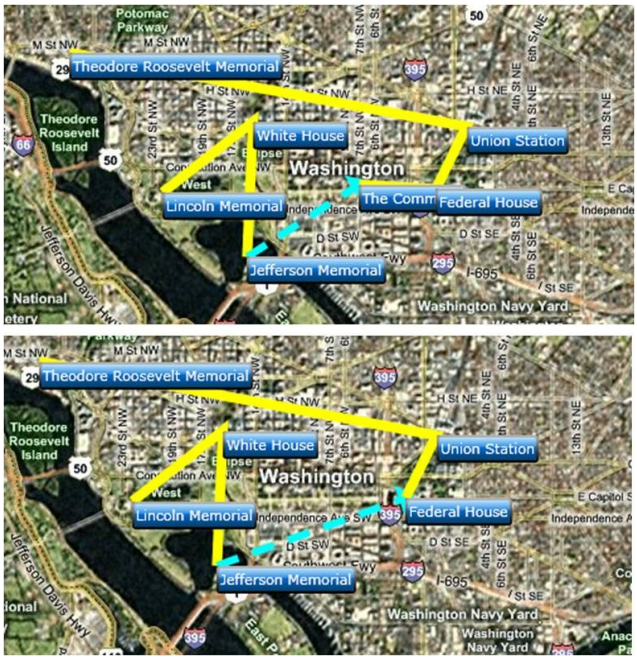

Figure 6: Recommended two-day travel routes in Washington DC. From top to bottom: (1) Travel route automatically generated by Photo2Trip, which contains seven attractions; (2) Travel route after user's interaction (removing *The Commons*).

2. The user can virtually walk on the map at various levels of geo-granularity, with road view or aerial view. Accordingly, different travel information will be shown.
3. At the city level view, popular attractions and the visiting order are displayed. Users are allowed to add/ remove any attractions and get an automatically re-generated travel route.
4. At the attraction level view, popular internal paths are provided, together with representative photos along each path. Users can also see a walk-through animation as if they were right on the scene.

3.1 User Interface

As shown in Fig. 5, the interface of the system contains four panels, i.e. *Input Panel*, *Place Panel*, *Map Panel*, and *Image Panel*.

Input Panel: Users input visiting time and location in this panel. Dates can be easily selected through a calendar interface. When users type the destination they want to search, popular destinations are suggested based on the destination discovering algorithm as introduced in Section 2.1.

Place Panel: Attractions are divided into three groups, *Current Trip*, *Recommendations* and *Other Attractions*. The content of each group will be explained in section 3.2. By clicking an attraction, users can see related information of the attraction, including representative internal paths, tags and photos.

Map Panel: A map is shown at the city level view with travel routes, or at the attraction level view with internal paths of each attraction. Users can zoom in/out, drag the map, select a region and view routes/paths in different ways.

Figure 7: Representative travel paths around the Lincoln Memorial. The path in the top figure costs about 2 hours and the path in the bottom one costs about half an hours. Users can see representative photos along each path.

Image Panel: Representative photos along an internal path are shown for each attraction. Users can enjoy the photos and click to see their locations on the map.

3.2 City Level View

As shown in Fig. 1, give a city, e.g. Washington DC, the system displays a route generated by our trip planning algorithm.

The system displays popular attractions in different groups in the Place Panel. Current Trip lists the attractions within a recommended route. Recommendation lists other popular attractions in the current city. If an attraction is added to the route by the user, it will be moved to Current Trip; while if it is removed from the route, it will be moved from Current Trip to Recommendation. The attractions listed in Current Trip are displayed in the Map Panel at the same time.

Fig. 6 shows two routes after user's interaction with our system. The details of the interaction are explained as follows. First, seven attractions were recommended to a user for a two-day trip in Washington DC. The user clicked each attraction and viewed the details (which will be shown in Section 3.3). The user removed the attraction "The Commons", for he did not plan to visit this attraction, and get a new route with the remaining six attractions.

Users can also add attractions to their trip. The most popular attractions in the same city are listed in the Place Panel. Users can select attractions form Recommendation and view the details of the attractions. If they want to visit an attraction, they can add the attraction to the Current Trip list and a new route will be generated. Through the procedure as described above, a customized result can be obtained.

3.3 Attraction Level View

As shown in Fig. 3, given an attraction, e.g. the Lincoln Memorial in Washington DC, the system automatically displays the most popular internal path based on our internal path discovering algorithm.

Figure 8: Internal paths in Forbidden City with different time costs. (a) 2-hour path; (b) 3-hour path; (c) 4-hour path; and (d) 5-hour path.

At the attraction level view, the system displays the internal path of the corresponding attraction in the Map Panel. Related tags of this attraction are shown to indicate the context of the attraction. Above the Image Panel is a button named Animate the trip, which can show users a walk-through animation along the internal path.

There are multiple representative travel paths within or around an attraction, and different paths may have different time costs. Fig. 7 shows two typical travel paths around the Lincoln Memorial, from which we can see the time cost and representative photos along each path. According to the detailed information shown at the attraction level view, such as tags and photos, users can make a decision whether an attraction should be kept in the route.

The time cost of each path is an important property for users to plan their trips. Our system can discover representative paths with different time costs. Fig. 8 shows different paths with different time costs in the Forbidden City, Beijing.

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