MOIR/UOTS: Trip Recommendation with User Oriented Trajectory Search

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***Abstract*—Trajectory search plays an important role in various applications such as trip planning and recommendation. However, most existing studies only focus on spatial proximity but ignore individual users' preferences. For example, it is inappropriate to recommend a route containing gravel roads to travelers without off-road vehicles. To accommodate various user preferences, we develop MOIR/UOTS, a trip recommendation system that supports User Oriented Trajectory Search (UOTS) [5], [7] based on our previous MOIR platform [2], [4]. Meanwhile, MOIR/UOTS also functions as a test-bed system for exploring and evaluating novel trajectory searching algorithms. In particular, we demonstrate how ordinary users can interact with MOIR/UOTS to search for trajectories with their preferences, and how MOIR/UOTS helps researchers to evaluate the performance of various algorithms.**

I. Introduction

The continuous proliferation of GPS-enabled mobile devices [8] (e.g., car navigation systems, smart phones and PDAs) and online map services (e.g., Google-maps[1], Bing-maps[2] and MapQuest[3]) enable people to log their current geographic locations and share their trajectories to web sites such as Bikely[4], GPS-Way-points[5], Share-My-Routes[6], Microsoft GeoLife[7]. In the meantime, more and more social network sites, including Twitter[8], Four-square[9] and Facebook[10], begin to support the applications of sharing locations/trajectories. The availability of such massive trajectory data creates various novel applications. An emerging one is trajectory search and recommendation [1], [5], [7], which is designed to find trajectories connecting (or close to) a set of query locations, e.g., a set of sightseeing places specified by a traveler, from a collection of trajectories made by other travelers. Travelers can benefit from such services when they are planning trips containing multiple intended places in an unfamiliar environment. Trajectory recommendation can be achieved by answering queries that only consider spatial proximity. However, in many real world scenarios, the spatial proximity is insufficient to provide satisfactory results, due to various preferences from individual users. For example, recommending the shortest route with several toll roads may be unfavorable to some budget-sensitive travelers.

To this end, we develop MOIR/UOTS, a proof-of-concept system with interactive visualization for trip recommendation while supporting various *user oriented features* (UOFs) from various domains (e.g., spatial, temporal, and textual domains). In particular, we demonstrate how MOIR/UOTS conquer the following challenges:(1) How to select and represent UOFs for both queries and trajectories? (2) How to constrain the search space of the UOFs to make the query processing efficient?

II. System Design

Figure 1 gives an overview of the MOIR/UOTS system which consists of three major modules: *query feature constructor*, *trajectory feature collector*, and *query engine*, where the first two modules deal with the first challenge, and the query engine deals with the second challenge raised in Section I.

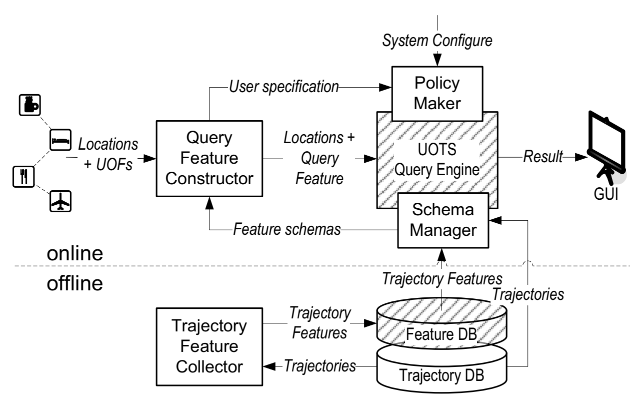

Fig. 1. MOIR/UOTS Overview

The query feature constructor accepts queries (a query is a set of locations along with UOFs), and transforms the UOFs into a *query feature* according to certain feature schemas, in an online manner. The trajectory feature collector extracts a set

[1]http://maps.google.com/
[2]http://www.bing.com/maps/
[3]http://www.mapquest.com
[4]http://www.bikely.com/
[5]http://www.gps-waypoints.net/
[6]http://www.sharemyroutes.com/
[7]http://research.microsoft.com/en-us/projects/geolife/
[8]http://twitter.com/
[9]http://foursquare.com/
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of *trajectory feature* tuples from trajectories in a trajectory database; and organizes them in a feature database, in an offline manner. The query engine employs a *Schema Manager* to consistently manage the trajectory features and the query features. As features may cross domains, the query engine employs a *policy maker* to configure different collaborative search strategies among the domains to make the query processing efficient. Finally, the query engine returns and visualizes the top k most similar trajectories ($k \geqslant 1$) on a Web-based GUI.

Modeling UOFs: We model the UOFs at MOIR's database kernel [3]. We focus on describing how to represent trajectory features, while representing query features can be done similarly. A trajectory is associated with a *Trajectory Feature* which consists of a *Global Feature (GF)* and a set of *Local Features (LFs)*. The global feature describes the general properties of the trajectory, and the local features describe the properties of individual GPS points in the trajectory. Each (local or global) feature may contain a set of *Feature Components*, where each feature component indicates an attribute of interest, and is in the form of $(schema, value)$. Table I shows examples of local and global features of trajectories. With the help of a

TABLE I. EXAMPLES OF TRAJECTORY FEATURE TABLES

Trajectory	Trajectory Feature
Tr_1	(GF(id_1,(transMode:string, "bus"), LF{(p_1,(roadType:string, "highway"), ... (p_{200},(roadType:string, "tollway"), ...})
Tr_2	(GF(id_2,(travalStyle:string, "group"), LF{(p_1,(speed:real, 10), ...})

set of operators that are defined based on the involved data types, trajectory features can be retrieved using common SQL queries.

The acquisition of UOFs is a time-consuming process as some features may be difficult to acquire. For example, whether a trajectory passes through a tollway can only be determined after map matching the trajectory. Fortunately, we can pre-process the trajectories in an off-line manner and store the obtained UOFs into a feature database.

Multi-Domain Collaborative Search: To measure the similarity between a query q and a trajectory τ in multiple (i.e., spatial, temporal, and textual) domains , we need to define a similarity metric for each domain. For example, Longest Common Subsequence (LCSS) [6] is applied to evaluate both spatial and temporal similarities. Textual features are encoded with TF-IDF and are transformed into a high dimensional vector. Thus, Jaccard coefficientis applied to measure the textual similarity. By combining the similarities in different domains, the similarity between q and τ is defined in Equation 1.

$$sim(q, \tau) = \sum_i \alpha_i \cdot sim_i(q, \tau) \quad (\sum_i \alpha_i = 1), \qquad (1)$$

where parameters α_i controls the relative importance of the i-th domain, and sim_i indicates the similarity between q and τ on the i-th domain. Note that MOIR/UOTS provides an interface allowing users to adjust the parameters at query time. The trajectories with high $sim(q, \tau)$ values are returned as final results.

To efficiently answer UOTSs, MOIR/UOTS applies a collaborative searching approach [5], which conducts trajectory search in multiple domains concurrently and produces a pair of comparable tight bounds (the upper and lower bounds of $sim(q, \tau)$ to constrain the search space. To further enhance the efficiency of processing UOTSs, a heuristic searching strategy based on priority ranking is developed to schedule the multiple query sources in multi-domains effectively. Demonstration participants will be able to learn more details on the working mechanism of the query engine.

III. DEMONSTRATION OUTLINE

MOIR/UOTS is developed as an extension module on top of our previous MOIR platform [2] which has a built-in digital map consisting of around $38K$ road segments and $55K$ road intersections in Beijing and a trajectory data set containing over ten thousands taxis in Beijing. The user interface of MOIR/UOTS contains two panels: *human-computer interaction* and *spatial data visualization*, as shown in Figure 2. Demonstration participants can simply identify query locations by clicking on the map, and the recommended trajectory is visualized on the digital map.

Conference audiences are encouraged to try features in the following domains in either an individual or an integrated manner.

1) **Spatial domain.**
Spatial proximity is a basic feature of measuring trajectory similarities. Audiences can choose a spatial-only-query (e.g., only considering spatial similarity in Equation 1), and it is also considered as a baseline of query result and is conducted every time for the purpose of comparison by default.
2) **Temporal domain**.
Temporal influence associated to spatial query locations is meaningful in many practical scenarios. MOIR/UOTS provides an interface that users can associate timestamps to query locations. For example, an audience can specify a rough travel plan by associating 8:30, 10:00, 13:30, and 15:30 with Airport, Summer Palace, Forbidden City, and Great Wall, respectively (refer to the popup window in Figure 2).
3) **Textual domain**.
To support complex semantics of user preferences, the MOIR/UOTS system also supports features described in textual format (e.g., travel style, road condition, etc.). The relative importance of textual attributes can be adjusted in the configuration panel on the left side of the GUI.

When an audience indicates an intended place by clicking on the map, a window containing the corresponding local features will be popped up (refer to Figure 2). Meanwhile, the audience can also specify the features using the operation panel on the left side of the GUI (refer to Figure 2).

Ranking based on the combination of different features (refer to Equation 1) is enabled in the demo system, and users can select one or more features to conduct UOTSs. The relative importance of different features (domains) can be adjusted in the configured panel (which is usually shrunk under the operation panel). Several sets of query examples are also prepared in order to present UOTSs in a convenient way.

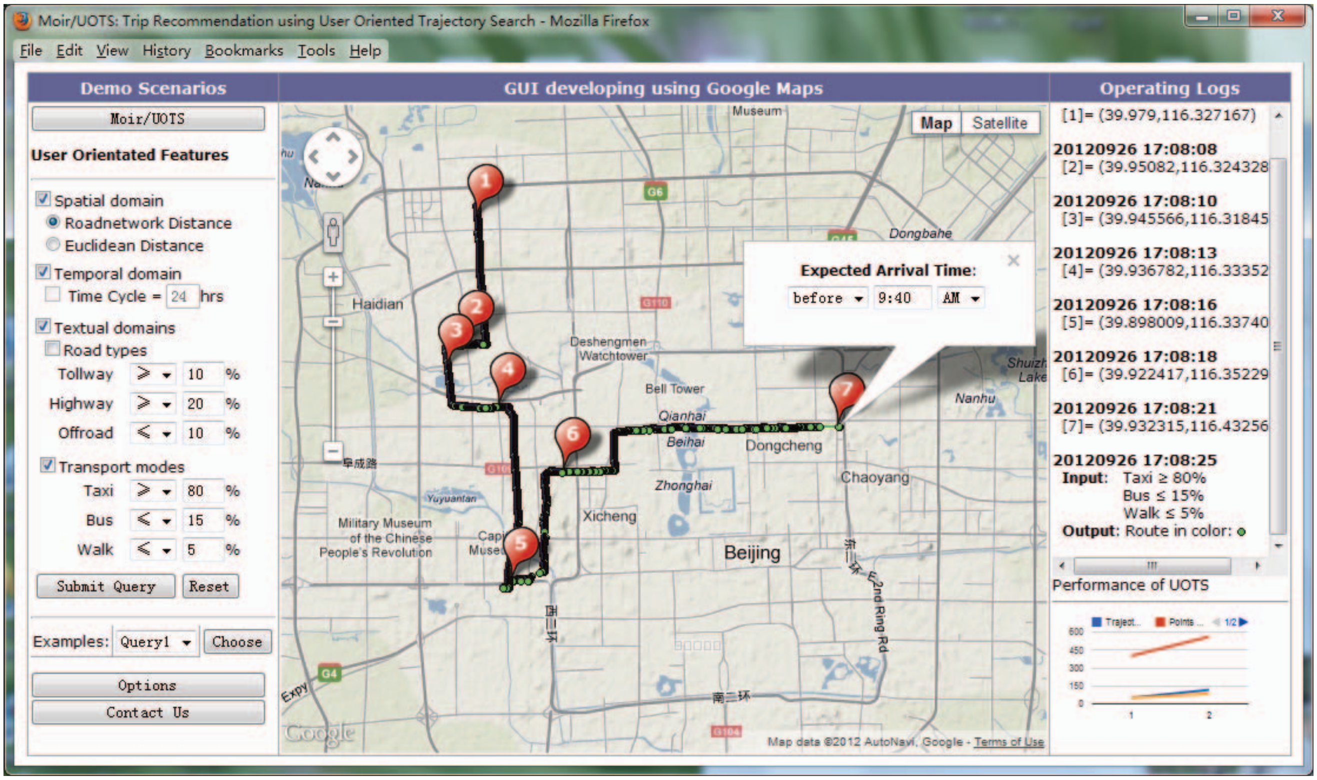

Fig. 2. The interface of MOIR/UOTS.

The main performance metrics of UOTSs are CPU time, the number of visited trajectories and the number of accessed data points. Once a query processing finishes, the three experimental performance metrics are also shown in line chart on the right bottom (refer to Figure 2), to illustrate the query performance intuitively.

While a wide range of user groups may be interested in this trajectory recommendation system, we mainly target at the following two categories of audiences: service providers that provides intelligent trajectory sharing and trip recommendation services, and the database researchers in the area of spatiotemporal data management and analysis.

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V. Conclusion and Outlook

We present MOIR/UOTS, a trip planning and recommendation system for implementing and evaluating algorithms of User Oriented Trajectory Searches. Our prototype system shows the modeling of user oriented features in database kernel and utilizing them to fulfill user preferences for trajectory search and recommendation is an efficient and powerful technique. In the future, it is of interest to consider enriching the domains of UOFs, and increasing the number of query locations for large scale applications.

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