Tourism Management 62 (2017) 76–88

Contents lists available at ScienceDirect

Tourism Management

journal homepage: www.elsevier.com/locate/tourman

Personalized multi-period tour recommendations

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HIGHLIGHTS

- Novel Filter-First Tour-Second framework for generating personalized touristic tours.
- Computational experiments on a unique dataset from Foursquare considering 4 US cities.
- Iterated Tabu Search algorithm for generating tours considering various restrictions.
- Collaborative Filtering for selecting optional attractions based on user preferences, online reviews and number of check-ins.
- New best solutions for Multi-period Orienteering Problems with Multiple Time Windows.

ARTICLE INFO

Article history:
Received 22 June 2016
Received in revised form
2 March 2017
Accepted 6 March 2017

Keywords:
Orienteering problem
Iterated tabu search
Tour recommendations
Collaborative filtering

ABSTRACT

During a trip planning, tourists gather information from different sources, select and rank the places to visit according to their personal interests, and try to devise daily tours among them. This paper addresses the complex selection and touring problem and proposes a “filter-first, tour-second” framework for generating personalized tour recommendations for tourists based on information from social media and other online data sources. Collaborative filtering is applied to identify a subset of optional points of interest that maximize the potential satisfaction, while there are some preselected mandatory points that the tourists must visit. Next, the underlying orienteering problem is solved via an Iterated Tabu Search algorithm. The goal is to generate tours that contain all mandatory points and maximize the total score collected from the optional points visited daily, taking into account different day availabilities and opening hours, limitations on the tour lengths, budgets and other restrictions. Computational experiments on benchmark datasets indicate that the proposed touring algorithm is very competitive. Furthermore, the proposed framework has been evaluated on data collected from Foursquare. The results show the practical utility and the temporal efficacy of the recommended tours.

1. Introduction

Trip planning is a complex and time-consuming process (Souffriau, Vansteenwegen, Vanden Berghe, & Van Oudheusden, 2013). Tourists need to gather information from paper-based and online data sources (e.g., travel guides, web sites, blogs etc) and make a selection of the points of interest to visit that correspond most to their personal interests. They shortlist and prioritize the points, while iteratively they try to design the tours and determine the visiting sequences subject to a set of hard and soft constraints. Apparently, numerous alternatives may emerge and besides the selection of points, the touring problem is computationally intractable and hard to solve. It typically maps to orienteering problems, in which the underlying mathematical models take into account a wide variety of restrictions and satisfaction metrics (Souffriau, Vansteenwegen, Vertommen, Berghe, & Oudheusden, 2008; Vansteenwegen, Souffriau, & Van Oudheusden, 2011; Zhu, Hu, Wang, Xu, & Cao, 2012). This paper presents a novel “filter-first, route-second” framework that captures the tourist's preferences based on social filtering as well as it generates high-quality personalized tour recommendations considering various intuitive constraints and realities.

It is evident that tourists increasingly abandon standard tours in

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http://dx.doi.org/10.1016/j.tourman.2017.03.005
0261-5177/

favor of more personalized options (Hyde & Lawson, 2003). Paper-based travel guides provide only generic recommendations that cannot meet the specific preferences of every tourist. On the contrary, one of the recently introduced functionality of digital travel guides is personalized tour recommendations (Anacleto, Figueiredo, Almeida, & Novais, 2014; Gavalas, Konstantopoulos, Mastakas, & Pantziou, 2014). Notably, the users of these digital tools do not only have access to the opinion and viewpoint of an expert but they can also obtain access to the opinion of their peers through text reviews. Furthermore, the content is shared with social media users and online reviewers, who can then continuously evaluate its quality and make sure it is up-to-date.

Despite recent advances, the vast majority of the existing expert or automated tour planning systems are still inflexible in the sense that they provide the user with a set of pre-computed tours instead of personalized recommendations based on given set of preferences and constraints. For instance, many of the systems proposed in the literature do not consider the category of the points to be recommended or the user's preferences with respect to each category (e.g., De Choudhury et al., 2010; Dunstall et al., (2003); Kim, Kim, & Ryu, 2009; Roy, Das, Amer-Yahia, & Yu, 2011). Furthermore, the recommendations made often ignore the visiting horizon, the tour lengths and the traveling distances, and the interdependencies between the consecutive daily tours. Our framework addresses all these issues in a number of ways and introduces a very rich formulation for addressing the touring problem that, to the best of our knowledge, appears for the first time in the literature.

The contributions of this paper can be summarized as follows. First, we propose a collaborative filtering (CF) technique for point recommendation (Deshpande & Karypis, 2004). Given a set of *mandatory* points selected by the tourist this technique estimates preferences and recommends an additional set of *optional* points that are expected to maximize satisfaction. We acknowledge that it is challenging for a tourist (with limited knowledge of the currently popular points of interest and attractions in the city) to select the complete subset of places to visit that will maximize the utility of the tour. Instead, the tourist's input is much more likely to be limited to a small set of mandatory points, chosen based on personal interests and word-of-mouth. Second, we develop a network-based integer programming mathematical model to capture the multi-day touring problem. The aim is to decide, for each day of the planning horizon, the mix of optional and mandatory points, as well as to determine the visiting sequence that maximizes the utility of each daily tour. Our formulation takes into account temporal constraints (e.g., multiple time windows, maximum tour lengths and travel time constraints) as well as other user-defined restrictions including budget restrictions for entrance or other type of fees and category quotas (e.g. a maximum number of museums to visit each day). The objective is to maximize the total collected profit or score from the visited optional points. The resulting model can be abbreviated as the Multi-Period Multi-constraint Orienteering Problem with Multiple Time Windows (MP-MC-OP-MTW) and it is solved via an Iterated Tabu Search (ITS) metaheuristic algorithm. Our approach is capable of producing high-quality heuristic solutions in very short computational times.

We assess the performance of the proposed models and algorithms through extensive computational experiments using both artificial and real-life data collected from Foursquare for four main US cities, i.e., New York City, Pittsburgh, Boston and San Francisco. We found that our framework generated multi-day tours with short waiting times, high collected scores and high utilization levels. Notably, compared to the existing orienteering problem literature, our model formulation is more flexible and provides a unique combination of characteristics. To our knowledge, the only model in the literature with multiple periods and multiple time windows is that of Tricoire, Romauch, Doerner, and Hartl (2010). For this reason, we used their datasets to benchmark our metaheuristic algorithm and the results verify its competitiveness.

The remainder of the paper is organized as follows. Section 2 comments on the existing literature. Section 3 provides a formal description of the multi-period personalized tour design problem. Section 4 presents the proposed framework and describes in detail all major algorithmic components. Computational experiments assessing the value of the proposed framework, along with a comparative performance analysis, are presented in Section 5. Next, Section 6 discusses how the proposed framework can be implemented in ways that enhance visitor satisfaction and enable destinations to better promote their tourism resources. Conclusions are drawn in Section 7. Finally, note that for the purpose of brevity we will primarily use the term *point* and interchangeably with the terms *location, event, venue, activity, attraction* and *point of interest*.

2. Related work

Research on trip planning and personalized tourist guides have recently attracted significant attention. The so-called tourist trip design problem has been initially introduced by Vansteenwegen and Van Oudheusden (2007). In this seminal work the Orienteering Problem (OP) is used as the basis for modeling the single daily tours. Each attraction, event, activity or point of interest in a city is associated with a profit (or score). The pairwise travel times between the points are known, and the main restriction is that the total tour duration should not exceed a predefined time budget. The objective is to design the tour so that the collected profit or the number of visited points is maximized (Gunawan, Lau, & Vansteenwegen, 2016; Vansteenwegen, Souffriau, Berghe, & Van Oudheusden, 2011).

During the last decade, the above archetypal OP model has been enhanced in various ways to capture multiple user constraints. Vansteenwegen and Van Oudheusden (2007) and Gavalas et al. (2014) discuss the following problem characteristics and constraints: (i) planning tours for multiple days; (ii) grouping the points under different categories and limiting the number of categories to be visited during a tour; (iii) grouping the points as mandatory and optional with the aim to cover all the mandatory points; (iv) hard and soft time windows (e.g. opening and closing hours, admission hours, weather dependencies, accessibility restrictions for disabled tourists); (v) multiple time windows for selected points during the same day or during the planning horizon; (vi) budget constraints (e.g. entrance fees, tickets, and accommodation fees); and (vii) other preferences (e.g. lunch breaks).

A rich multi-day trip planning model has been recently proposed by Souffriau et al. (2013), namely the Multi-Constraint Team Orienteering Problem with Multiple Time Windows (MC-TOP-MTW). Besides multiple time windows on the same day and daily tour duration restrictions, this model considers that every location is associated with several attributes, and every attribute has a budget that cannot be exceeded. These constraints can be seen either as knapsack or as max-n type constraints. For example, budget limitations for entrance fees and maximum number of art locations to visit on a single day. An Iterated Local Search (ILS) algorithm combined with a Greedy Randomized Adaptive Search Procedure (GRASP) is developed for solving the MC-TOP-MTW. Note that the “teams” allow the modeling of multiple days as well as the modeling of multiple tours for the same day.