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Using a heuristic algorithm to design a personalized day tour route in a time-dependent stochastic environment

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HIGHLIGHTS

- We design personalized day tour routesin a time-dependent stochastic environment.
- A heuristic algorithm involving random simulation and hybrid evolution is proposed.
- A case study at Jiuzhai Valley is conducted to evaluate the method's performance.
- Our approach could design more personalized and realistic tour routes for tourists.

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ABSTRACT

A substantial transformation has occurred in tourist behavior in the postmodern tourism era, where the tourism market is dominated by the demand for tailored experiences. Therefore, the design of personalized tourist routes plays a fundamental role in improving tourists' travel experiences and the success of tourist attractions. This study proposes a hybrid heuristic algorithm based on random simulation (RS-H^2A) to design a personalized day tour route in a time-dependent stochastic environment. To evaluate the performance of this algorithm, we conducted a case study at Jiuzhai Valley in Sichuan, China. The results of paired sample t-tests indicated that the proposed algorithm performed significantly better than existing methods. Furthermore, our proposed approach had the ability to design more realistic and personalized routes for tourists than previous methods. We designed an experiment to further explore how uncertain environments affect tourists with different levels of risk awareness.

1. Introduction

A significant transformation has occurred in tourist behavior during the postmodern era, whereby tourists increasingly prefer personalized trips to pre-organized or general tourist packages (Hyde & Lawson, 2003; Kotiloglu, Lappas, Pelechrinis, & Repoussis, 2017; Rodríguez, Molina, Pérez, & Caballero, 2012; Uriely, 2005; Yeh & Cheng, 2015). However, personalized trip planning is a complex and time-consuming process (Rodríguez et al., 2012; Souffriau, Vansteenwegen, Vanden Berghe, & Van Oudheusden, 2013; Zhu, Hu, Wang, Xu, & Cao, 2012) which involves selecting points of interest (POIs) and scheduling of trips (Kotiloglu et al., 2017; Souffriau, Vansteenwegen, Vertommen, Berghe, & Oudheusden, 2008). This issue has been denoted as the "tourist trip design problem" (TTDP), which involves tour route planning for tourists, and maximizing their entertainment while considering numerous constraints (Vansteenwegen & Van Oudheusden, 2007).

As the significant contributions of TTDP-related research for improving tourists' experiences (Wong & McKercher, 2012) and for enhancing the competitive advantages of various attractions have been increasingly recognized (Kang & Gretzel, 2012; Vittersø, Vorkinn, Vistad, & Vaagland, 2000), the emerging field of TTDP research has generated an extensive body of literature over the past several decades (Hsu, Lin, & Ho, 2012; Lee, Chang, & Wang, 2009; Liu, Xu, Liao, & Chen, 2014; Rodríguez et al., 2012; Tsai & Chung, 2012; Zheng, Liao, & Qin, 2017). However, despite some recent advances, research on the design of personalized tour routes is still in its infancy.

Most studies have designed personalized tourist routes based on

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deterministic assumptions, which are often unrealistic. In reality, factors such as the weather, traffic, the limited capacity of POIs or unforeseen events are not only stochastic, but also time-dependent. Variations in such factors may move the TTDP from relative certainty to uncertainty (e.g., in terms of travel times between POIs or wait times at POIs) (Kok, Hans, & Schutten, 2012; Verbeeck, Vansteenwegen, & Aghezzaf, 2016). Thus, a deterministic TTDP solution can prove to be either infeasible or suboptimal in reality (Evers, Glorie, Ster, Barros, & Monsuur, 2014). Therefore, to obtain more realistic, personalized routes for tourists, we propose to explore the TTDP in a time-dependent stochastic environment, in which deterministic assumptions are relaxed, and various time-dependent stochastic factors are considered.

As we recognize the limitations of previous studies in dealing with the TTDP in a time-dependent stochastic environment, we intend to investigate the orienteering problem (OP) and the selective traveling salesperson problem (STSP), whose variants have already been successfully applied to model more complex versions of the TTDP (Feillet, Dejax, & Gendreau, 2005; Gavalas, Konstantopoulos, Mastakas, & Pantziou, 2014b; Gendreau, Laporte, & Semet, 1998b; Gunawan, Lau, & Vansteenwegen, 2016). However, methods involving stochastic OPs and STSPs cannot be used to solve the problem concerned in this study until the following aspects are considered.

First, these studies have emphasized the personalized spatial structure of a route (including POI selection and sequencing), but ignored time allocation. Zheng et al. (2017) addressed these limitations by introducing a four-step heuristic algorithm. Other than this study, discussion of this issue in the literature is negligible. In addition, although this study provided a comprehensive method, it was still based on deterministic assumptions.

Second, some studies of OPs and STSPs have conducted considerable research in the stochastic environment. However, due to the uneven spatial-temporal distribution of tourists throughout tourist attractions (Briassoulis, 2002; Brown, Kappes, & Marks, 2013; Tsai & Chung, 2012), the stochastic variables concerned in this study (e.g., travel times, wait times) are time-dependent. That is, the travel times between two vertices are stochastic functions that depend on the departure time from the first vertex, while the wait times at vertices change according to the arrival times. Therefore, the TTDP in this study should be considered in a time-dependent stochastic environment, which is more complicated than a stochastic environment.

Third, increasing attention has been paid to the time-dependent stochastic OP/STSP, as this problem formulation allows researchers to tackle congestion-related issues (Taş, Dellaert, van Woensel, & de Kok, 2014; Verbeeck et al., 2016). However, these studies deal with the problem under the assumption that all time-dependent stochastic variables (TDSVs) follow the same type of distribution function. This assumption is not the case in our study, as the TDSVs may follow different types of distribution functions in different timeslots, leading to difficulty obtaining a joint distribution function and converting the time-dependent stochastic TTDP into crisp models based directly on uncertainty theory.

Last but not least, although these studies have considered the problem in a (time-dependent) stochastic environment, they have not taken tourists' risk awareness into account. Tourists' preferences for "risk" are important personal characteristics, which greatly influence their decision-making behavior (Sitkin & Weingart, 1995). A risk-seeking tourist may prefer a route that has a large utility but a higher probability of failing to complete the trip during the budgeted time, compared with a risk-averse tourist who may choose a more "relaxed" path with lower utilities (Lau, Yeoh, Varakantham, Nguyen, & Chen, 2012).

To fill these gaps in the literature, this study focuses on personalized tour route design in a time-dependent stochastic environment, considering spatial-temporal route structure (including POI selection, sequencing and time allocation) and risk awareness of tourists. This problem is complicated due to the multiple constraints and TDSVs concerned. To overcome the difficulties involved, we designed a hybrid heuristic algorithm based on random simulation (RS-H^{2}A), which mainly consists of initialization, random simulation and hybrid evolution. This algorithm differs from current methods in three major ways: (1) it applies a random-simulation-based method to handle TDSVs, which follow different types of distribution functions; (2) it uses a hybrid evolution strategy to increase the algorithm's efficiency; and (3) it deals with the risk awareness of tourists in a time-dependent stochastic environment by combining the expectation optimization model (E-model) and the probability maximization model (P-model).

To evaluate the performance of this algorithm, we conducted a case study at Jiuzhai Valley National Park in Sichuan, China. The results of paired sample t-tests indicated that the proposed RS-H^{2}A indeed performed significantly better than the current methods. Moreover, our approach can design more realistic and more personally satisfying visitation routes for tourists. We also designed an experiment to further explore how uncertain environments affect tourists with different levels of risk awareness.

This study contributes to the field of personalized tour route design by providing a more sensitive approach for solving a time-dependent stochastic TTDP in the postmodern tourism era, where the tourism market is dominated by a demand for tailored experiences (Novelli, Schmitz, & Spencer, 2006). Our approach may be of great interest in the tourism sector. It can assist tourists in making decisions as they plan their trips, and offer realistic, personalized recommendations that suit their needs. The approach may also benefit tourist attractions, as it provides a better means to improve the quality of tourists' experiences and make attractions more competitive.

The remainder of this study is organized as follows. We present an extensive literature review of previous studies of the TTDP and other related problems in Section 2. In Section 3, a mathematical model to more successfully deal with the time-dependent stochastic TTDP is proposed. Section 4 explains the RS-H^{2}A in detail. In Section 5, we evaluate the performance of the proposed algorithm through a case study conducted at Jiuzhai Valley National Park. Section 6 summarizes the conclusions and proposes possible directions for future research.

2. Literature review

It is evident that the tourism market is increasingly dominated by the demand for tailored experiences, and that tourists are gradually abandoning standard tours in favor of more personalized trips (Hyde & Lawson, 2003; Kotiloglu et al., 2017; Rodríguez et al., 2012; Uriely, 2005). However, personalized trip planning is highly complex, as tourists need to gather information from different sources and evaluate numerous possible alternatives, with consideration for various constraints and objectives (Rodríguez et al., 2012; Souffriau et al., 2013; Zhu et al., 2012). Therefore, tourism recommendation systems have been extensively used to reduce information overload, and to assist tourists in making their trip planning decisions (Borràs, Moreno, & Valls, 2014; Buhalis & Law, 2008; Gavalas, Konstantopoulos, Mastakas, & Pantziou, 2014a; Gretzel, 2011; Rodríguez et al., 2012).

Lee et al. (2009) proposed an ontological recommendation multi-agent to recommend personalized travel routes to tourists in Tainan City best suited to their needs. Souffriau, Vansteenwegen, Berghe, and Oudheusden (2011) defined the planning of cycle