Sustainability Driven Recommender Systems

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Abstract

We focus on the goal of designing recommender systems (RSs) for sustainable tourism itinerary planning. In particular, we focus on the problem of rearranging tourist flows in order to protect popular destinations from overcrowding, as well as to stimulate the development of less mature destinations by distributing tourists throughout the territory. This topic is quite new in the recommendation literature, although it is well known in the tourism literature. We aim to transfer concepts from the field of tourism to the field of RSs in order to improve tourism development. Our approach is to take into account the goals of all the active stakeholders, and not to focus solely on tourists. Here, we propose a multistakeholder utility model for travel itinerary optimisation. We experimentally show that it is possible to mitigate the aforementioned environmental issues with a slight decrease in user satisfaction utility.

Keywords

recommender systems, tourism, sustainability, operations research, environment simulation

1. Introduction

Recommender Systems (RSs) are software tools that provide users with personalised access to information [1]. In the tourism domain, RSs are usually designed for the benefit of tourists and guide them to relevant destinations, collectively referred to as points of interest (POIs). To do this, an RS employs various machine learning techniques to evaluate the relevance score of each tourist-POI pair and then recommends the most relevant POIs. Travel recommendations should also help to manage tourist flows and favour the development of less mature areas. However, to assist that sustainable development of tourism, it is not enough to consider tourists as the only group of interest [2]. The benefit of other active stakeholders, such as host communities and destination management organisations (DMOs), should also be considered [3]. Hence, it is important to find recommendation policies that can benefit all stakeholders and improve the sustainability of local tourism. While this idea of sustainability driven recommendations has recently received attention in the literature [4, 5], there are many research gaps to fill. A general open challenge is that distribution of tourists across POIs shifts over time, that is, the state of the environment is constantly changing. In this paper, we consider a case study and propose a greedy solution to account for capacity constants, exposure constraints, and spacial coverage in dynamic environment where tourists arrive sequentially during the day. Addressing these constraints should be beneficial for the long-term improvement of the local tourism economy. Recommendations that follow these constraints are referred to as sustainable. The proposed design is tailored to the real-world scenario where this system is to be used.

IIR2022: 12th Italian Information Retrieval Workshop, June 29 - June 30th, 2022, Milan, Italy
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2. Case study problem

This section illustrates a case study that is a part of an industrial R&D project on tourism sustainability in an Italian tourism region. The target RS should stimulate various tourism activities in a village, such as, hiking adventures, as well as other leisure and cultural experiences. Given a set of POIs, for each arriving visitor the RS must generate a travel itinerary (an ordered subset of POIs), based on elicited preferences and the amount of time that the visitor is willing to allocate [6]. But, in addition to that goal, which is very common in tourism RSs, recommendations should rearrange tourist flows in order to satisfy: (1) capacity constraints, any POI can accommodate a limited number of visitors per time slot in order to avoid overcrowding or long queues, (2) exposure constraints, any POI must have its visitors during the day, (3) coverage constraints, visitors should be distributed evenly across the area of the village. Expected rearrangement of tourist flows should also be reasonable: recommended itineraries should consist of a sequence of POIs that complement each other to ensure a worthwhile flow at the destination. For example, a recommended itinerary might group thematically related POIs to increase visitor engagement. To impose this domain knowledge, the DMO was instructed to prepare an expert database of reference routes in which every route brings together coherent POIs in the order they should be visited. Our aim is to find the best subset of POIs belonging to one expert route (search among all expert routes) that is relevant to a particular tourist, fits disposable journey time, and preserves sustainability of territory.

3. Mathematical model

Multistakeholder approach is a general framework for understanding RSs where the end user is not the sole focus. According to this framework, a recommendation stakeholder is any group or individual that can affect, or is affected by, the delivery of recommendations to users [7]. To solve our problem, firstly, we formalise it from the point of view of the active stakeholders, and, secondly, we propose an optimisation model that accounts for the goals of every stakeholder.

3.1. Recommendation stakeholders

We adopt a utility-based approach and model independently user v utility, u_v, and environment utility, u_e, which includes the considered sustainable goals. Utility is computed for a generated itinerary, as the sum of the utilities of the POIs included in the itinerary. In optimisation section we will discuss how we generate a personalised itinerary based on these utility functions.

User utility is a function of tourist preferences and it is predicted by using a content-based RS [8] which scores and ranks the POIs available in the system (Figure 1). A content-based approach is here preferred because it makes easier to address the new user problem, i.e., the need to make recommendations to travellers that have not yet interacted with the RS. In that case the user profile is generated by using traveller typologies (e.g.: sun lover, action seeker, active sport tourist, family vacation, etc.) and self classification of the traveller in one of these typologies [9]. User utility can be computed as a sum of scores that the content-based RS assigns to the POIs that make up the generated itinerary. And it doesn't depend neither on time nor on the order in which selected POIs are presented in the generated itinerary.

Environment utility is a function of time and occupancy of the POIs that are selected for an itinerary. This function has the following properties: when POI occupancy is low, the utility encourages the RS to recommend that POI; when the occupancy of a POI is saturated, utility penalises for overcrowding it. We propose a monotonically decreasing function of occupancy, that has a parabolic shape (Figure 1). This function has its maximum at zero occupancy, equals zero when the occupancy is equal to the capacity (10 in the figure), and becomes negative after that. We conjecture that this definition will also improve spatial coverage of the recommended itineraries, that is, will stimulate a more even distribution of visitors over the area.

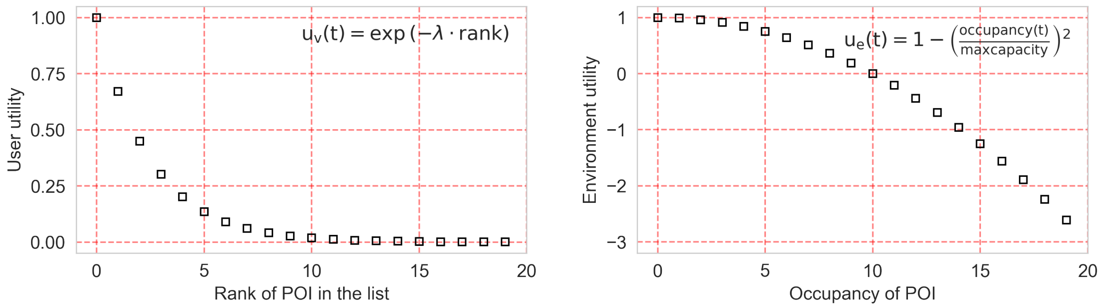

Figure 1: Utility functions. Left figure shows user utility ($\lambda = 0.4$) which depends on rank of a POI in ordered list generated by content-based RS. Right figure shows environment utility (max capacity of POI is 10 tourists). This utility is positive for an under-saturated POI, and negative for an overcrowded POI. The shape of the function and the steep decline encourage the RS, in order to maximise the environment utility, to include in the recommended itinerary new and under-saturated POIs

3.2. Assumptions

When a visitor arrives to the recommendation platform he/she will search for an itinerary that will start immediately. The RS finds a personalised itinerary by scheduling a subset of POIs within an expert route taking into account the predicted occupancy of the POIs in the next time slots and geographical constraints. Indeed, when a visitor experience a POI, he/she occupies a certain area and spends a fixed amount of time T at that venue. Also, there is a time cost τ of travelling between two POIs, which we assume is a constant value for any visitor.

3.3. Optimisation

For each incoming visitor the RS solves a bunch of similar itinerary planning optimisation problems, one optimisation problem for each expert-based route, and then choose the solution that is the best among the solutions found in the different expert-based routes. We consider in more details one of such itinerary planning problem. We maximise under time constraints (itinerary time should be less than time a visitor is willing to allocate) the cumulative utility of the generated itinerary, that is, the sum of the utilities of the POIs that constitute the itinerary:

$$\max_{x_1,\ldots,x_n} \sum_{i=1}^{n} x_i \cdot [u_{v,i} + \alpha \cdot u_{e,i}(t)]$$

where x_i is an indicator function (equals 1 if the itinerary contains the i-th POI and 0 otherwise); n is the total number of POI candidates in the considered expert-based route; $u_{v,i}$ is the visitor v utility for visiting the i-th POI; and $u_{e,i}(t)$ is the environment utility which depends on the time and occupancy of the i-th POI. The parameter α determines the trade-off between the two objectives. This optimisation problem can be posed as a search for a path of maximum utility on a graph, where the graph is represented by ordered POIs in one expert route. Our optimisation algorithm is based on breadth-first search graph exploration heuristic, called beam search [10]. The main idea of beam search is to iteratively expand the most promising partially generated routes (candidates) based on defined utility score (Figure 2).

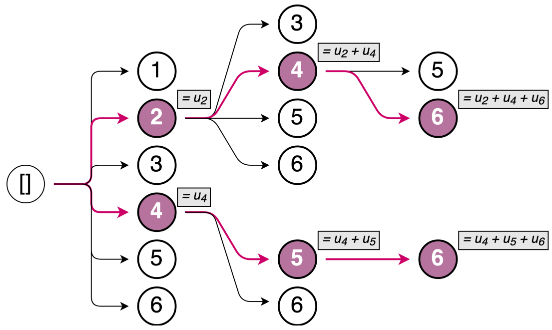

Figure 2: The process of beam search (beam size = 2) greedy optimisation for expert-route with 6 POIs. At each step the algorithm tries to expand already generated routes (candidates) with next available POIs, than sorts results based on cumulative utility and preserves only best beam size results. The best itinerary is to be found among [2],[4],[2,4],[4,5],[2,4,6],[4,5,6] generated candidates

4. Experiments

We utilised a two-step recommendation approach in order to simulate the environment of an Italian village. In the first step, we applied a content-based RS to rank for each incoming visitor the available POIs based on visitor's typology. In the second step, we searched for the best subset of POIs across all available expert routes to maximise the given combination of user and environment utilities. We created 20 geographically distributed POIs throughout the village with random stay times, transition times, and with the same capacity value (10 visitors). We simulated the arrival of 5 types of tourists, where the tourists of one type have the same preferences and receive the same recommendation list by the content-based RS. In our experiment, visitors arrive one after another with a Poisson inter-arrival rate. We ran our simulation at the highest possible tourist arrival rate that our environment can accommodate without POIs overcrowding (assuming we are ignoring tourist preferences). We defined 5 expert routes with a total duration of 5-6 hours each. Key information about the experiment is represented in Table 1.

Simulation results are illustrated in Figure 3. Each point in figure (left) represents user vs. environment (average) recommended itinerary utility for a specific value of the parameter α. There is a clear trade-off between user and environment utilities. Figures (right) show how itinerary planning algorithm distributes visitors to different POIs during the day, and what occupancy profile for each POI we expect. We analysed three cases: α = 0, α = 0.2, and α = 4.

In the first case, RS does not account for POI occupancy issues. In the second case, RS greatly improves environment utility while slightly reducing user utility. In the third case, environmental goals are fully taken into account: RS can satisfy capacity constraints and encourage exploration of unpopular POIs.

Table 1
Summary of the simulation parameters in the Italian village

Open time from 6 am to 6 pm, inter-arrival rate 1.4 tourists per min
20 POIs, stay time 20-40 min, transition time 5-20 min, capacity 10 visitors at max
5 types of visitors, max journey duration time for each visitor 3 hours
5 expert routes, total duration time 5-6 hours each

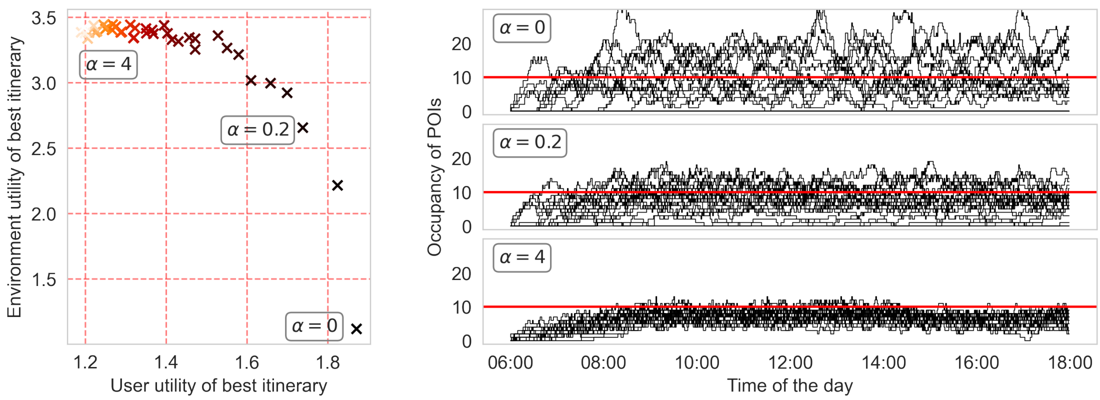

Figure 3: Simulation results. Left figure shows user vs. environment utilities as a function of trade-off parameter α. Right figures show how itinerary planning algorithm distributes visitors to different POIs (one curve for each POI) during the day, and what occupancy profile for each POI we expect based on different values of parameter α. Red horizontal lines represent maximum allowed capacity for each POI

5. Conclusions

The proposed utility-based RS balances conflicting objectives and reduces over recommendation of popular POIs. It helps to promote unpopular POIs and increases spatial coverage by distributing tourists across an area at little cost to user satisfaction. This multistakeholder approach can improve tourism planning when it is necessary to balance the goals of various stakeholders, as a result, there is a chance to increase the sustainability of local tourism.

However, the proposed model has some limitations. We are aware that in real life, our assumptions are not always fulfilled. In particular, there is a chance that visitors will not follow the suggested itinerary, and even if they will, there is uncertainty about when they will start it and how long they will spend at each POI. In addition, we want to improve the optimisation step and search for optimal itineraries over all permutations of POIs, not just among predefined expert-based routes. These limitations will be addressed in future work.

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