A Mixed Integer Model for the Stamina-Aware Sightseeing Tour Problem

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1 Introduction

Personal navigation systems have experienced a rising interest in the past few years thanks to the ever-increasing ubiquity of smartphones and in-car navigation systems. In their simplest forms, the goal is to calculate routes that are optimized with respect to criteria such as travel time and distance. Various systems have been proposed that allow for additional dynamic aspects to be included in the optimization process such as a user's current context [1], multi-modal transportation [2] and weather [3].

The stamina-aware sightseeing tour problem (SASTP) was first proposed by Wu et al. [4] and is defined as follows: Given is a tourist with a time and stamina budget and a number of sightseeing spots. Each spot can be visited by using one of several available methods (e.g., short tour, guided tour, extensive tour, etc.) and each method requires a certain amount of time and stamina, but gives a certain degree of satisfaction in return. Traveling between sightseeing spots takes time and also consumes stamina. After visiting a spot, the tourist may spend some time to take a break and regain stamina. The goal is to construct a sightseeing tour that contains a selection of spots with corresponding visiting methods that maximizes the tourist's overall satisfaction and does not exceed his time and stamina budget.

In [4] a predator search (PS) metaheuristic was proposed for this problem. Solutions are represented in a straightforward way by a set of quadruples, each specifying the spot to be visited, the order in the final tour, the visiting method, and the length of the break after the visit. The algorithm uses two phases: First an auxiliary solution is generated on the basis of a randomized algorithm. Then it is improved by a neighborhood search phase that optimizes each of the solution attributes. A drawback of this approach is that the search space is very large, therefore only instances with 10 to 20 sightseeing spots were considered.

2 A Mixed Integer Programming Model

We propose a mixed integer programming (MIP) model for the SASTP by exploiting its characteristics:

- The visiting order can be regarded as a traveling salesman problem (TSP) and efficiently modeled by a standard subtour-elimination formulation.
- Each visiting method can be regarded as an item in a multidimensional knapsack problem (MKP) where the satisfaction degree is its value while time and stamina are the resources. The possibility of converting time to stamina through breaks can be handled via a transformation constraint.
- Since a homogeneous linear function is used for recovering stamina, the breaks can be considered cumulatively over all spots, i.e., the solution only needs to specify the total duration over all breaks, but not when to do them.

With the above considerations, our model only uses two sets of decision variables: one for the selection of visiting methods in the MKP part and one for the route construction in the TSP part.

For the computational experiments we randomly generated instance sets with 10, 20, and 30 sightseeing spots in the same way as in [4]. Each set contains 10 instances. The MIP model was solved by the ILOG CPLEX optimizer and on average it took less than a second for instances with 10 spots, 4 seconds for instances with 20 spots, and 370 seconds for instances with 30 spots to be solved to provable optimality.

3 Conclusions and Future Work

Looking at the characteristics of the PS metaheuristic and the MIP model, it is obviously beneficial to combine both concepts in a hybrid approach. While the essential drawback of PS was the enormous search space, pure MIP approaches usually have a bad scalability. In a hybrid approach we plan to use very large neighborhood search (VLNS) based on the MIP model that combines the advantages of both approaches. In such an algorithm the solution only needs to specify which spots to be visited and the other components are obtained by VLNS.

This problem also has many interesting extensions that are relevant in practice. The inclusion of further resources (e.g., money) is straightforward and does not effect the structure of the problem. Furthermore we can specify multiple modes for traveling between the sightseeing spots (e.g., by foot, public transport, taxi) with different time, stamina, and other resource requirements. This extension would change the problem significantly since the visiting order subproblem cannot be regarded as a classical TSP anymore. Another extension would be to consider time windows for each sightseeing spot since in general they are not opened all the time. Similar to the vehicle routing problem with time windows, this would be a very complex aspect. Last but not least it is also plausible to include human interaction in the optimization process because the tourist might have specific constraints and/or preferences on his own that cannot be modeled in general, but should be considered in the individual case.

References

1. J. Baus, A. Krüger, and W. Wahlster. A resource-adaptive mobile navigation system. In *Proceedings of the 7th international conference on Intelligent user interfaces*, IUI '02, pages 15–22. ACM, 2002.
2. K. Rehrl, S. Leitinger, S. Bruntsch, and H. Mentz. Assisting orientation and guidance for multimodal travelers in situations of modal change. In *Intelligent Transportation Systems*, pages 407–412. IEEE, 2005.
3. B. Wu, Y. Murata, N. Shibata, K. Yasumoto, and M. Ito. A method for composing tour schedules adaptive to weather change. In *Intelligent Vehicles Symposium*, pages 1407–1412. IEEE, 2009.
4. B. Wu, W. Sun, Y. Murata, K. Yasumoto, and M. Ito. A stamina-aware sightseeing tour scheduling method. In *Proceedings of the 13th annual conference companion on Genetic and evolutionary computation*, GECCO, pages 81–82. ACM, 2011.