Optimization of Circular Cycling Routes based on Mobile Sports Tracking Application Data

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Abstract

In this paper we give an overview of ongoing research related to the optimization of circular cycling routes based on mobile sports tracking application data. Novel methods are needed for an efficient solution of the NP-hard arc orienteering problem (AOP) on a large road network. By using a cycling network extracted from OpenStreetMap (OSM) data and edge-wise popularity values derived from workout trajectories collected by sports app users, we aim to find attractive cycling routes of preferred length.

Keywords: arc orienteering problem, multi-objective optimization, metaheuristic, tabu search, cycling

1 Introduction

Sports tracking applications provide different functionalities from tracking one's workouts and performance to social motivation via e.g. route recommendations by other trackers. An interesting alternative would be to automatically provide suggestions of attractive circular routes, which start and end at a given point and conform to the length set by the user. Existing applications designed for this purpose rely mainly on simple approaches, such as converting the problem to multiple shortest path problems, and they do not aim at finding optimal routes.

In operations research, the problem of maximizing the collected profit such that the traveling time of the route does not exceed the time constraint, is known as the Orienteering Problem (OP) or for example the selective travelling salesperson problem [1]. This is an NP-hard problem, meaning that in order to find a sufficient solution within adequate time, heuristic methods are to be applied.

2 Previous work

Arc routing variants of the OP, where profit is related to graph arcs instead of vertices have gotten far less attention than for example the tourist trip design problem [2]. Recently, Cycle Trip Planning Problem (CTPP) has been identified as a promising application area of AOP. Previous works on CTPP have applied Greedy Randomized Adaptive Search Procedure (GRASP) [3] and a recursive depth-first search-like algorithm [4]. Both methods have provided near-optimal solutions within few seconds using the East Flanders cycling network covering almost 3000 arcs. Real-time performance requires that a large amount of routes are calculated beforehand; in [3] all shortest paths between vertices within 20 km of each other and in [4] shortest paths between each pair of vertices are calculated off-line.

3 Data and methods

3.1 Network

A cycle network that would guarantee a seamless experience of high-quality paths and furthermore be topologically sound for routing purposes is rarely available beyond city scale. The nation-wide *Fietsknooppunten netwerk* in the Netherlands and parts of Belgium is in this respect exceptional. We use a directed cycle network extracted from the crowdsourced OSM data. By matching a set of over 23,000 cycling tracks recorded by the users of Sports Tracker [5] mobile application to the network, each arc has been given a popularity value reflecting the number of cyclists who have traversed along the arc.

3.2 Heuristics

Aside from the used network, our approach differs from previous work in the applied heuristics (tabu search [6]) and more realistic consideration of optimal route from the viewpoint of the cyclist. In addition, our goal is to restrict the memory requirements and thus limit the pre-processing phase. The basic idea of the approach is to iteratively improve the current solution by searching the best available alternative in its neighborhood. By using a list of graph vertices, which are unavailable ("tabu"), we avoid repeating a cycle of solutions, which makes the search more aggressive. To avoid getting trapped to the local optima, diversification strategies will be applied.

Similar to [4], we avoid traversing same arcs twice, but in addition believe that recreational cyclists would in general prefer circular routes that take them to varying terrains, i.e. are rather round-shaped than traversing e.g. back-and-forth along a river (Figure 1). By defining one objective function based on the principles of multi-objective optimization [7], we aim to find routes whose length would conform to the target distance set by the user, yet be popular, as well as cover wider areas if possible.

Figure 1. The effect of using additional objectives controlling the shape of the route for improving the circular route suggestions. (a) Optimization is done based on only arc-wise popularity and the route's target distance. This has led to a route whose shape reminds a horseshoe. (b) The area within the route has been used as an additional optimization criterion, which has led to a more round route. Map data © OpenStreetMap contributors

4 Preliminary results and discussion

To gain wider practical value, the routing algorithm should be applicable on a more complex network than what has been used in previous CTPP studies. Our preliminary results show the potential of tabu search in solving the CTPP, as well as the challenges related to fast computation and appropriate weighting of different objectives. Because optimality depends also on personal and situational factors, computation of many alternative routes rather than just one globally optimal should be supported. By excluding arcs that have been traversed by only a few people we can better guarantee the route's bike friendliness as well as increase the efficiency of the routing service.

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