Approximation algorithms for NP-hard geometric problems

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NP-hard problems are of great importance in the field of computer science since their discovery in the 70s. Their huge computational complexity has led to the development of so-called approximation algorithms that provide approximate solutions in polynomial time. In this thesis, several NP-hard problems with a geometric flavor and corresponding approximation algorithms were studied in detail, implemented in Python and tested on real-life data sets.

Introduction

The output of an approximation algorithm yields an approximation to the optimal solution of a problem with a guarantee of accuracy. This means that if there is an NP-hard problem like metric TSP (where the goal is to find a minimum cost cycle that visits every vertex exactly once in a complete graph with nonnegative edges), an approximation algorithm with a factor of, say, 1.2 finds a solution that has a cost of at most 1.2 times the optimal cost. I.e., if the shortest tour has a length of 100 kilometers, the found solution has a length of at most 120 kilometers.

Results

For the metric TSP problem, we studied and implemented a factor 3/2-approximation algorithm due to Christofides. We then discussed geometric clustering problems known as k-center, k-median and k-means. Roughly speaking, in these problems one looks for a partition of data points into k clusters according to some meaningful pattern. We implemented approximation algorithms based on a local search technique and applied them to a data set of road traffic accidents provided by geo.admin.ch. In this way, we succeeded in discovering several hotspots of accidents in different regions in the canton of Bern. We visualized our results on a public website.

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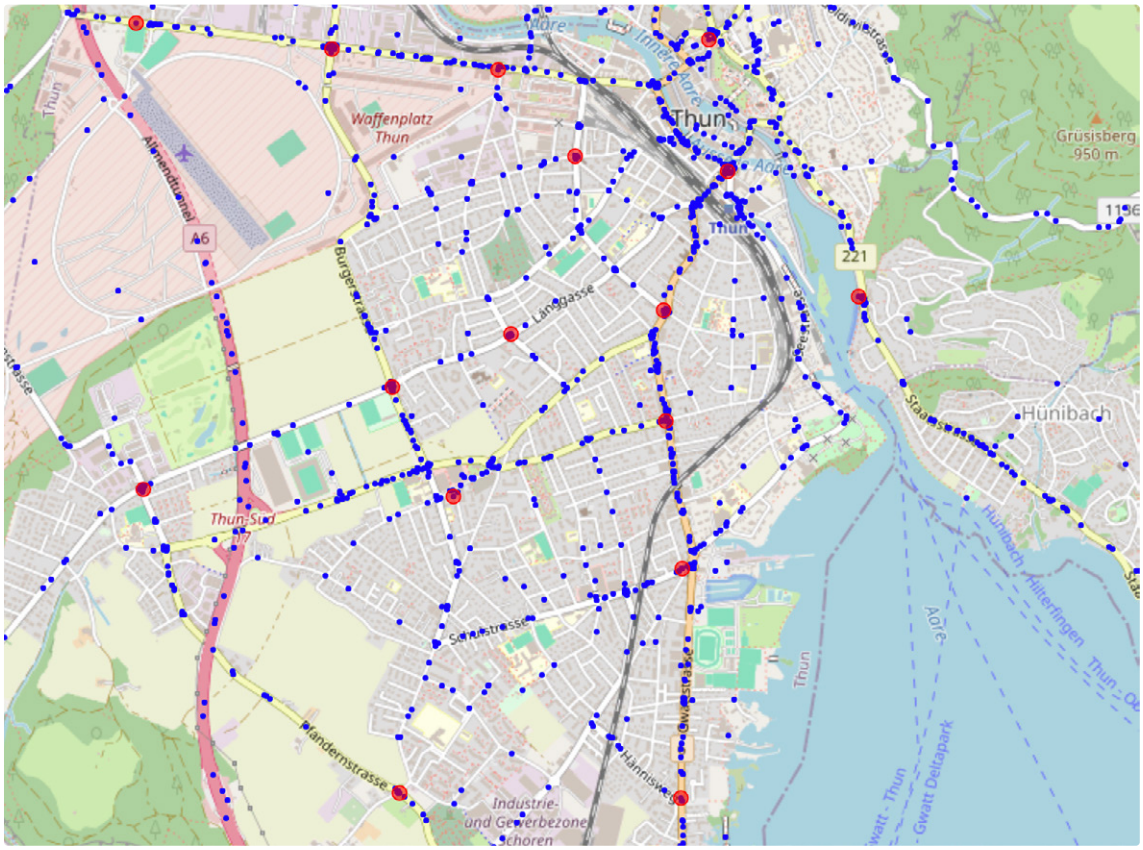

Snapshot of the accidents that occurred in Thun (the blue points) as well as the centers found by the approximation algorithm (red circles)