Vertiefende Aspekte der Geoinformation
Assignment 4

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1 Description

The submitted document was created within the course Selected Topics of Geo-information Science. It covers assignment number 4 from the summer semester 2023. In it, the maximal covering location problem (MCLP) was utilized to investigate the service and demands for hospitals in Styria. In particular, the service radius (r) of hospitals and how it relates to the number of people served in the area. For this, the municipalities of Styria have been simplified to geometric centroids with the respective population as an attribute. And the service area is assumed to be a circle with radius r, that has its center in the hospital location.

All processing has been done in Python using the Allagash Module. The code is available in Google Colab and on Github.

Within the Assignment 3 tasks have been given:

- Find the minimum service radius with which a total coverage is possible.
- Find a position for an additional hospital that would significantly decrease the minimum needed service radius.
- Is a buffer around the hospitals the best way to describe their service area? Are other approaches more suitable?

This document tries to answer these questions and explore how MCLP can be used to get insights into the spatial patterns created by hospitals and districts.

2 Maximal covering location problem

The maximal covering location problem (MCLP) tries to maximize the number of clients that can be covered by a fixed number of facilities. It was first formulated by Roland Church and Charles Revelle in 1974 in the paper The Maximal Covering Location Problem. Within the context of this work, the problem is solved using a mixed integer linear programming solver. Church and Revelle state that the objective of the MCLP is to maximize the number of people served within the desired service distance.

This will formulate the MCLP by using a set of decision variables (service and demand client), a set of constraints that set the number of services constant and an objective function to maximize the number of clients covered.

3 Analyzing the service area radius

The area of Styria is divided into 286 municipalities which centroids are used as demand locations, 53 hospitals exist within Styria, these have been chosen as supply locations. For the Algorithm used, the precision was set to 500 m, to avoid long computation time, this gave a **resulting Service Area Radius of 34.50 km**.

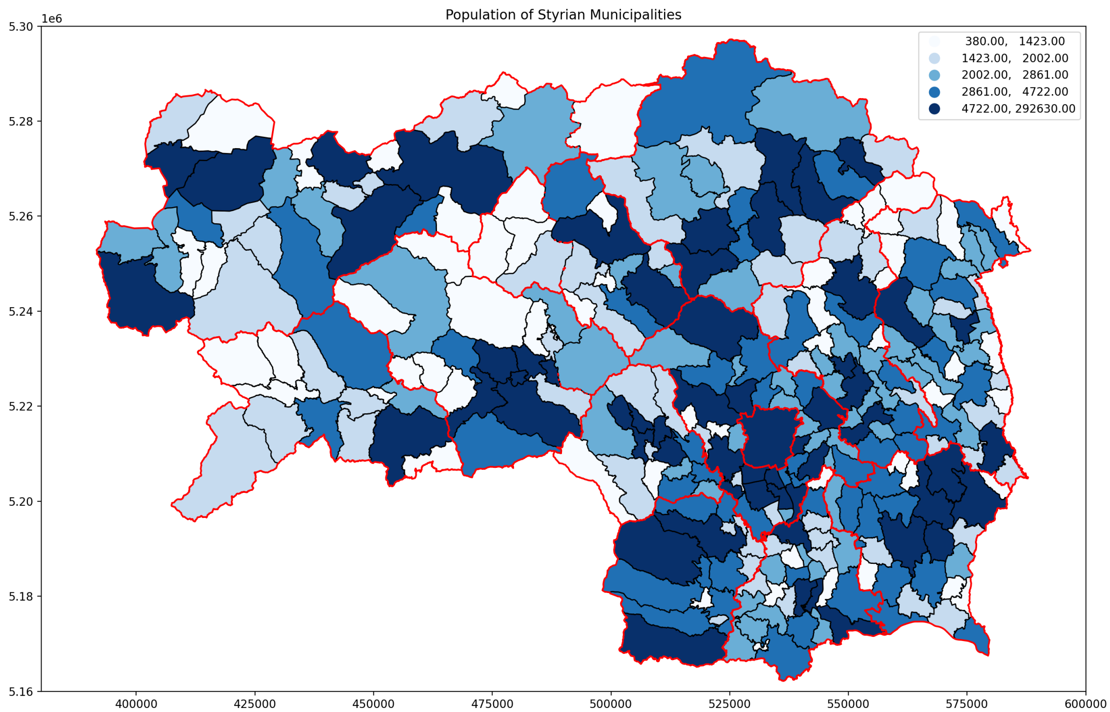

Figure 1: Population in Styrian districts (2020). Red: higher districts.

Figure 1 depicts the population in the Styrian districts. The strong populated east, center location is the Capital Municipality Graz. Largely populated areas seem to appear together, while less dense areas also cluster together. A higher number of communities with large populations appears on the right-hand side of the map, when split in the middle. As can be seen in figure 2 the service area is nearly equivalent to the largest distance from a municipality to the nearest hospital. Calculating the distance from the blue colored district in figure 2 to the nearest hospital gives 33.79 kilometers, which is relatively close to the service area radius found using the MCLP problem. Many hospitals are located in the capital municipality, it has to be noted, that in some cases these are specialized facilities that don't represent general purpose hospitals.

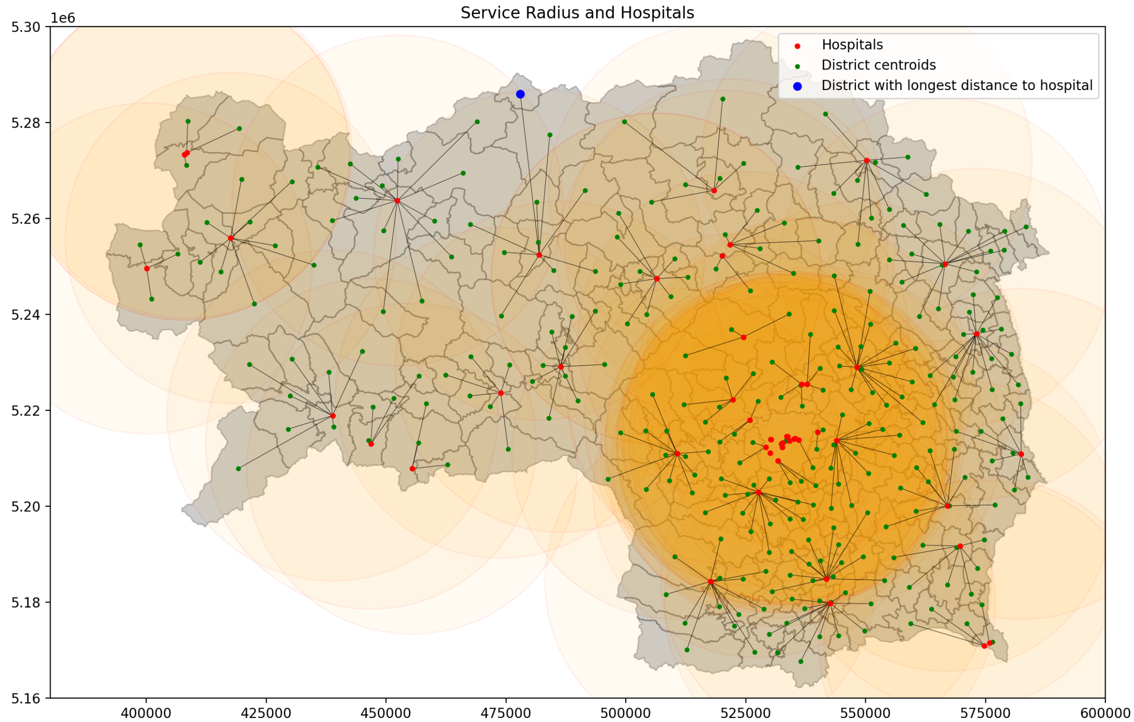

Figure 2: Hospitals with service areas and nearest municipalitys

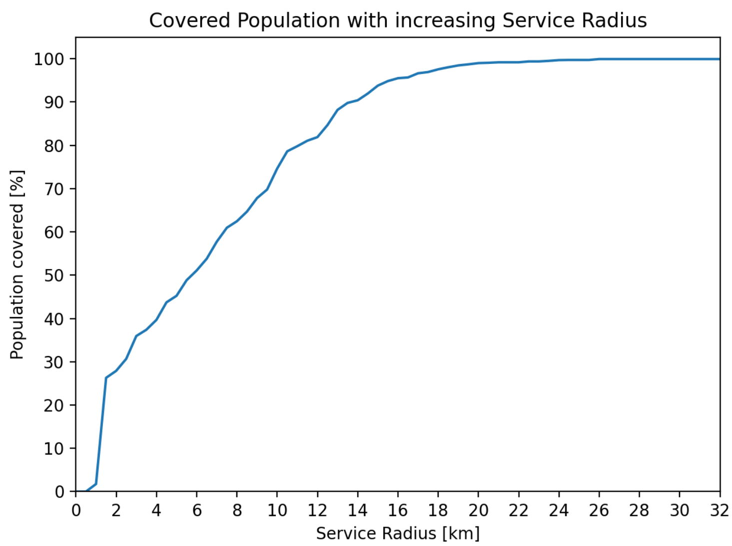

Figure 3: Fraction of covered population with increasing service radius.

Figure 3 shows the fraction of people covered relative to the population of Styria. It can be observed that from 0 to ca. 1.5 km the fraction rises steeply. Then from 1.5 to 14 it seems to grow linear. After that, it resembles the curve of a logistic growth model, suggesting that increasing the radius above a coverage of 90% does not result in the same return rate as increasing the radius when the coverage is for example 50%

4 Impact of adding a new Hospital

The district marked blue in figure 2 was chosen to be the new hospital at X: 477992.080 Y: 5285982.394 — UTM33N EPSG:32633. Since the objective in the Assignment was to minimize the radius of the service area, and this location has the largest distance to the nearest hospitals, it seemed promising to use it as a new location. This, however, does not take into regard the real demand of population that is created by the municipalities surrounding the new location. So the outcome represents a theoretical experiment, rather than advice for a new location. **The addition of the new location resulted in a radius of 24 km**, which is a decrease of 10.5 km or 30.44% compared to the original result.

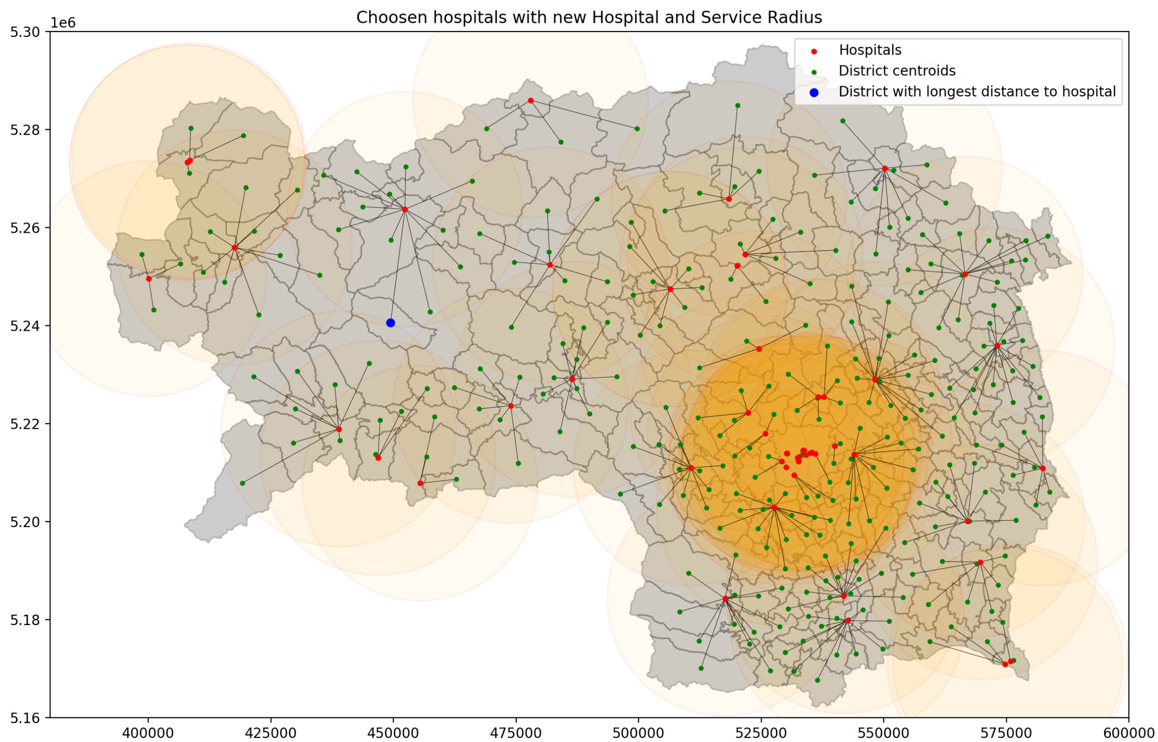

Figure 4: New Hospital with new Service Radius

5 Concerns regarding the service area

The service area is assumed to be a circle, which does not take into concern obstacles, larger districts than municipalities and travel time to the nearest hospital. The circle assumes that all municipalities that lie in distance r of the hospital have the same travel time. Also, it is not sure if an ambulance will drive to the nearest hospital or to the hospital of the district the patient resides in.

A better approach would be to use the district the hospital is located in as the service area for it. Then again, how would one go about increasing the service area or add a new hospital? A buffer could be used on the shape but it is unclear how accurate this would be. The service area could also be calculated using routing with the Dijkstra Algorithm, routing from every municipality-Capital to the Hospitals and using the hospital with the least driving time.