Transport time analysis of Tübingen

Frederic Becker
Matrikelnummer 4082451
frederic.becker@student.uni-tuebingen.de

Jan-Niklas Dihlmann
Matrikelnummer 4117847
jan-niklas.dihlmann@student.uni-tuebingen.de

Abstract

Every day a large number of people decide which mean of transport to pick to reach a certain destination. To compare the travel times of driving, bicycling and walking in the city of Tübingen, we created a pipeline for creating isochrone maps querying the Google Maps API. This special map visualizes travel times for a route that goes from a specific starting point to any location on the map. In addition, we regressed travel times with a linear regression model based on horizontal and vertical distances between the starting and destination location. We found that the isochrone maps captured a salient traffic characteristic of Tübingen and that bicycling is a good alternative for driving, in case no hills have to be climbed. However, our work is limited to a single starting location in Tübingen.

Github Repository: Isomap

1 Introduction

Every day, billions of people use different modes of transportation to get to work, school or university. Travel time usually depends on the choice of transport, the distance of the route, the traffic situation and, in some cases, even the weather conditions. Nevertheless, route planning services such as Google Maps [Goonea] manage to provide reliable estimates of travel time. Isochrone maps show how travel times evolve in the environment. More specifically they display the travel time required to get from a fixed starting point to locations on the map. This visualization of location-dependent travel times is particularly useful for identifying anomalies and large shifts within travel times. For example this publicly available map [gmine] displays the minimum travel time from Paris to any place in France for bike, train and car.

In this report, we will describe our approach of creating an isochrone map for the city area of Tübingen, Germany considering travel times by foot, bike and car. This process consisted of three steps: First, we created a grid of locations depicting the area of Tübingen. Second, we queried the Google Maps API for travel times and elevation data. Third, we visualized the obtained data in an isochrone map. In addition, we regressed travel times with a linear model to identify possible salient differences between the means of transportation and to test to which extent travel times within Tübingen can be predicted by the horizontal and vertical distance between the start and destination of a route.

In the next section we will describe our data collection scheme. In section 2 we will present the isochrone maps and the regression results. In the last section we will summarize and conclude.

2 Data collection and mapping

We developed a data collection pipeline to query samples of travel time from an arbitrary location of origin and a corresponding region of destinations. This pipeline receives a location of origin and queries samples of travel time in a destination grid, that can be specified in sampling rate, bound size and transportation type. For the instance of Tübingen we specified the origin as the *Tübingen Rathaus* with coordinates $(Lat:48.5204497, Lng:9.0534181)$ and the region of destinations as a squared surrounding area of $16km^2$ in size sampled by 1600 evenly arranged grid points.

To obtain estimated travel times we queried the Google Maps Distance API [Gooneb] for walking, bicycling and driving. It is import to note, that the Google API moves destinations that are not reachable by the specified mean of transport to the nearest reachable position. As a consequence, the final sample locations differed between transportation types even tough the same destination grid was queried. We stored the entire JSON retrieved from the Google API including directions, bounds and most importantly duration. Finally we obtained a dataset with 1600 samples per transportation type and 2573 unique locations. To provide the regression analysis with vertical distances, we additionally created a pipeline for the Google Maps Elevation API [Goonec] to query and store the elevation for each individual site in our dataset. Since the Google API is costly and we used up our free contingent it was not possible to increase the sample size.

To create the isochrone maps we divided the range of travel times into 10 equally sized bins and then plotted the contours of the corresponding locations within a bin which defined regions that can be reached in similar time from the starting position. This visualization corresponds to the definition of an isochrone map. The elevation map was constructed in a similar fashion, whereby we additionally highlighted locations that are below the origin location with dots.

3 Isochrone Maps

Isochrone maps are an elegant tool for visualizing travel times for a route that goes from a specific starting point to any location on the map. It provides an intuitive way to analyze the differences in transportation time between different modes of transportation and helps to find bottlenecks in the underlying city structure and the corresponding traffic system. This is especially interesting for Tübingen, as there is always a debate which transportation is the fastest. Tübingen is also known as a large one-way street for cars, so it will be interesting to see if this is reflected in the corresponding isochrone map.

The isochrone maps for walking, bicycling and driving are presented in Figure 1a-c. The isochrone map for walking forms a radial pattern spreading from the origin point more or less evenly in all directions. The inner city can be reached within 8 minutes and the margins of the map within 80 minutes. The isochrone map for bicycling is more irregular structured. The contours are more elongated and extend parallel to the river Neckar. Using the bike, the inner city can be reached within 4 minutes and the margins of the map within 36 minutes. The isochrone map for driving is similar to bicycling map. Interestingly, the map includes single blobs of high travel times that are not part of the other maps and which represent most-likely areas like woods in which driving is not possible. By car the inner city can be reached within 6 minutes and the margins of the map within 27 minutes.

Locations near the origin are faster reachable by foot and by bike than by car. This is because the starting point is near the historic center of Tübingen, which is closed to cars, therefore Google Maps suggests a large detour for this area. In addition, destinations along the eastern riverbed appear to be difficult to reach by car. This area fits very well with the Gartenstraße which is fastest to reach via a one-way street in the direction of the historic center, which results in a long detour for cars. Furthermore, the same one-way street crosses the Neckar and connects the lower and upper city centers. According to the isochrone maps, the lower city center is quicker to reach by foot and by bicycle than by car. The isochrone maps can thus capture and depict a prominent traffic architecture of Tübingen very well.

4 Regression Analysis

The travel time algorithm underlying the Google Maps API is not publicly available. Still, it can be assumed that it integrates a variety of datapoints on traffic, distance and past user travel times in a A* fashion algorithm. The aim of our analysis was to test to what degree this travel time calculation can be approximated by two rather simple predictors namely the horizontal and vertical distance between the starting and the ending location of the route and to describe the differences in travel time between the different means of transportation numerically.

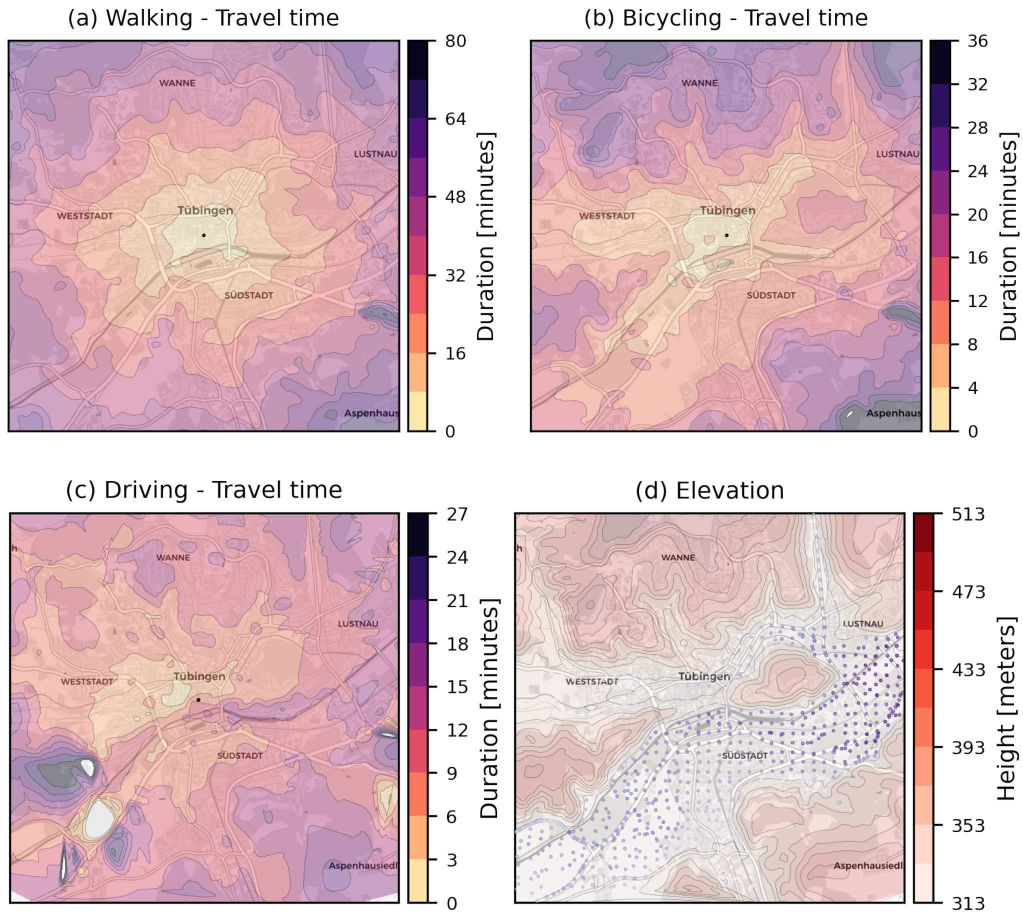

Figure 1: Isochrone maps (a,b,c) and elevation map (d) of the city Tübingen, Germany. The black dot in the isochrone maps denotes the origin point, which is the Tübingen Rathaus. Each other location on the map is color coded indicating the time (in minutes) it takes traveling to that specific location. The elevation map shows the relative height (in meters). Additional points indicate regions that are lower than the origin (darker equals lower).

We fitted two regression models for travel time each considering different predictor variables. The horizontal model M_h only included the horizontal distance between the origin and the destination as predictor. The combined model M_{hv} included additionally the absolute vertical distance between the origin and the destination as predictor. We chose an additive model formulation that estimates the speed differences between driving, bicycling and walking explicitly. In addition, we constraint the model to have an intercept of zero as it does not require any time to reach one's own position. Travel time was given in seconds and distances in meter. The combined model achieved a lower mean absolute error (M_{hv}: 2.5 min, M_h: 3.4 min) and a lower BIC value than the horizontal model (M_{hv}: 64566, M_h: 67315). The combined model thus explains the data better and is able to regress travel times with a average deviation of 16%.

The combined model estimates that a car travels horizontal distances at 17 km/h ($\beta = 0.25$, CI $= [0.24, 0.25], p < .001$), a bicycle slower at 12.8 km/h ($\beta = 0.03$, CI $= [0.02, 0.04], p < .001$), and a pedestrian significantly slower at 4 km/h ($\beta = 0.60$, CI $= [0.59, 0.61], p < .001$), as illustrated in Figure 2a. Thus bicycling is only slower to an extent of approximately 4 km/h given a flat route. The different velocities are also reflected in the different time scales of the isochrone maps (see Fig. 1). Vertical distances are traveled with a speed of 2 km/h ($\beta = 0.93$, CI $= [0.69, 1.18], p < .001$) by car (see Fig. 2b). Significantly slower is the bike with 0.6 km/h ($\beta = 5.47$, CI $= [5.13, 5.82], p < .001$), whereas walking is significantly faster than bicycling with 1 km/h ($\beta =$

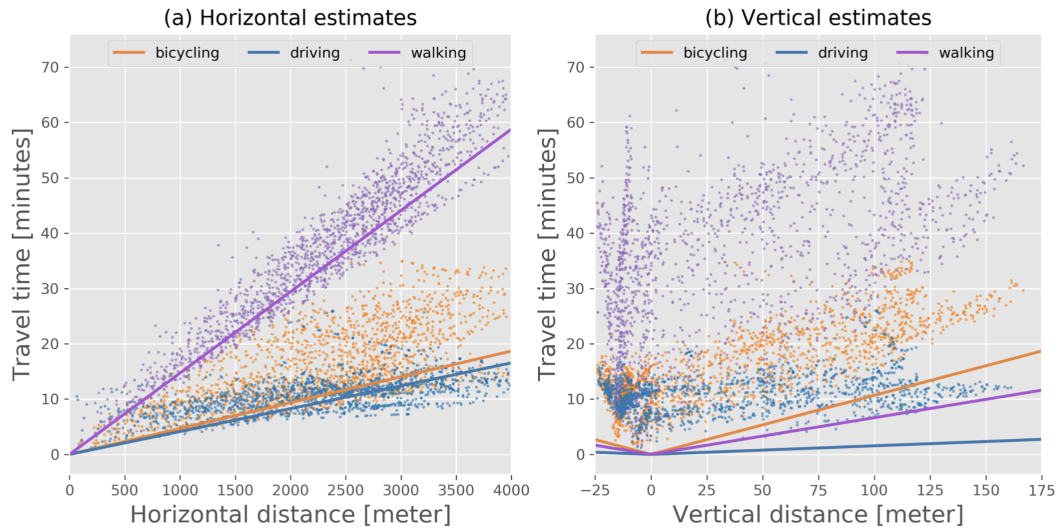

Figure 2: Regression of travel times in Tübingen. Fits of the combined model presented for driving, bicycling and walking per predictor variable i.e. horizontal distances (a) and vertical distances (b). Confidence intervals of the regression lines were omitted as they are too narrow to illustrate.

-2.43, CI $= [-2.77, -2.08], p < .001$). The car is slowed down by vertical distances by a factor of 8.7, the bike by a factor of 22.5 and the pedestrian only by a factor of 4.2. This resembles very nicely that walking is relatively insensitive to the topology which is mirrored by the radial pattern in the isochrone map for walking, whereas the isochrone maps for driving and bicycling are more shaped by the topology. Furthermore, the estimates imply that bicycling is a serious alternative to driving as long as no major vertical distances have to be climbed. This corresponds very well to the fact that people bicycle less frequently in hilly cities than in flat cities [Ger18].

5 Conclusion

We presented a pipeline for creating isochrone map for arbitrary locations. and demonstrated it at the example of Tübingen. The presented isochrone maps were able to capture basic traffic characteristics of Tübingen, in addition the analogous regression analysis of travel times suggested that bicycling is a good alternative to driving but forfeits if vertical distances have to be traveled whereas walking is pretty insensitive to vertical distances. However our results are very limited. First, all our results rely heavily on the accuracy of Google's travel time computation. Second, our analysis is only valid for the specific starting location and may differ for other starting locations and cities.

References

[Ger18] Regine Gerike. Ergebnisdarstellung zum 11. erhebungsdurchgang mobilität in städten srv 2018. TU Dresden, 2018.

[gmine] gmilloue. Paris city map travel time, Accessed Jan. 20, 2022. [Online].

[Goonea] Google. Google maps, Accessed Jan. 25, 2022. [Online].

[Gooneb] Google. Google maps directions api, Accessed Jan. 25, 2022. [Online].

[Goonec] Google. Google maps elevation api, Accessed Jan. 25, 2022. [Online].