Improving bicycle routing by modifying a road network

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Summary

Cycling is an important mode of environmentally friendly transportation. However, the choice of a pleasant cycling route, is affected by many factors, including relief, road surface, availability of green spaces and others. This paper investigates a method of modifying the road network to enhance cycling routes with the information of surface roughness. To achieve that we utilize data from the accelerometers from everyday smartphones mounted on bicycle handlebars. Based on the gathered data, road sections are extended, or contracted and new cycling routes are calculated. The proposed methodology produces short alternative routes with less uneven road sections.

KEYWORDS: Bikeability, Modified road-network, Routing, Accelerometer, Bicycle

1 Introduction

The 2022 Intergovernmental Panel on Climate Change (IPCC) identifies the transition to biking as a CO2 mitigation option that aligns synergistically with multiple Sustainable Development Goals (SDGs)(Lee et al., 2023). Encouraging more people to choose bicycles over cars is not only a relevant goal for many cities, but also an economically viable and sustainable alternative.

One city actively involved in this endeavour is Augsburg, situated in the southern part of Bavaria. Augsburg embraces the shift towards biking, citing reasons beyond CO2 mitigation. The city recognizes the relatively small spatial demand, the noiseless character of biking, and the positive impact on well-being as additional motivations. The question then arises: How can such ambitious goals be achieved with limited resources?

Several scientific works on bikeability tried to assess the question from different directions. Some used forms to ask bikers what they experience as positive (Jonietz and Timpf, 2012; Wahlgren and Schantz, 2012; Handy et al., 2010) others tried to use physical measures to understand what the best pull factors are (Krisp et al., 2021). The idea behind most research is to make using bicycles as appealing as possible.

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A way of gathering data on the quality of road surfaces is using accelerometer data. Accelerometers are being used to detect road surfaces for cars (Hoffmann et al., 2013; Dong and Li, 2021) and bicycles (Hoffmann et al., 2013; Zang et al., 2018). Mostly to map the information or use machine learning methods to find potholes. This work tries to use the data to enhance routing mechanisms.

When going from A to B the mode of transportation and the pleasantness of the chosen route are important factors and both depend on the purpose of the journey. Going to work is a repeating cause and the driving factors might be more the travel time than the beauty of landscape. On the other hand, when exploring a city via bicycle it is possibly the other way around and time is not so much of importance while sightseeing is. This difference of interests can also be connected to the type of bicycle that is being used for the journey. A racing bike without any suspension and high pressure tyres is more meant for going fast over straight and even roads, while mountain bikes do not mind non asphalt roads that are uneven.

Thus, to make cycling more appealing this work explores the idea to create an alternative route based on a *combination* of length and road surface roughness. The roughness is measured with an accelerometer. To evaluate this methodology, a case study is conducted in the Jakobervorstadt of Augsburg. There, a route based on length is compared with one based on the compound value visually.

2 Data and methods

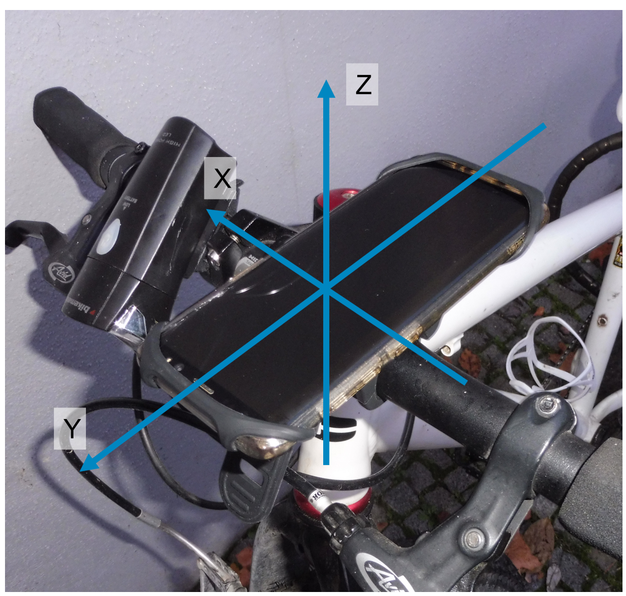

Figure 1: Mounting of the smartphone to the handlebar

In this work *OSMnx* is used to obtain a road network and calculate the shortest route based on a weight (Boeing, 2017). It also offers the option to download a network for bicycles. In this region no underpasses exist, which could cause problems with the routing.

The accelerometer data is gathered with a simple rubber holder for the handlebar of a bicycle as is shown in figure 1. Thus, the smartphone is mainly affected by the roughness beneath the front wheel of the bicycle. The software used to collect and store the resulting acceleration data in csv-files is the *physics toolbox suite* [1] by *Vieyra Software*. It is free to-, and easy to use. It saves the linear acceleration in X / Y / Z directions (compare fig. 1) together with a GPS point among other data. Because the measure frequency of the accelerometer is higher than that of the GPS many measure points share the same geotag.

For the data accumulation each edge of the network is measured twice, each time with a different type of bicycle. One being a mountain bike with suspension, the other a normal bicycle that is rentable at many points in the city without suspension and thinner wheels. The same rubber holder and smartphone is used for each of the measurement tours.

The index value with which the edge length is manipulated is calculated with the following formula:

$$I(i) = \alpha * \frac{\frac{(|a_i| - \bar{a})}{std(a)} * \frac{1}{\exp(\beta * \frac{v_i}{max(v)})}}{max(|I(i)|)} \tag{1}$$

- $I(i)$ is the index of measure point i
- a is the Z-acceleration
- v is the travel speed
- $\bar{x}$ is the total mean
- $std()$ is the standard deviation
- β, α are factors that were obtained by testing

The acceleration in vertical direction is damped by the travel speed and then divided by the highest index value so that the index is between -1 and 1. The idea behind the damping is that at higher travel speed the vertical acceleration caused by a unevenness is bigger than that of the same unevenness, but with lower travel speed. This index is small when the roughness of the surface is low and vice versa. It is then added one so that it potentially ranges from 0 to 2 and subsequently multiplied with the length of the edge to create a network with shortened and enlarged lengths. The altered length is called *felt-length*.

3 Results

Map 2 shows the region of the case study with its road network classified by the index created with formula 1. The area was selected because of the heterogeneous road network with all kinds of different surfaces. In tendency the southern and central part of the region features roads that are smaller and narrower than in the north. In the south some have cobblestones, or are laid with gravel around the park.

[1] `https://www.vieyrasoftware.net/`; last access: March 12, 2024

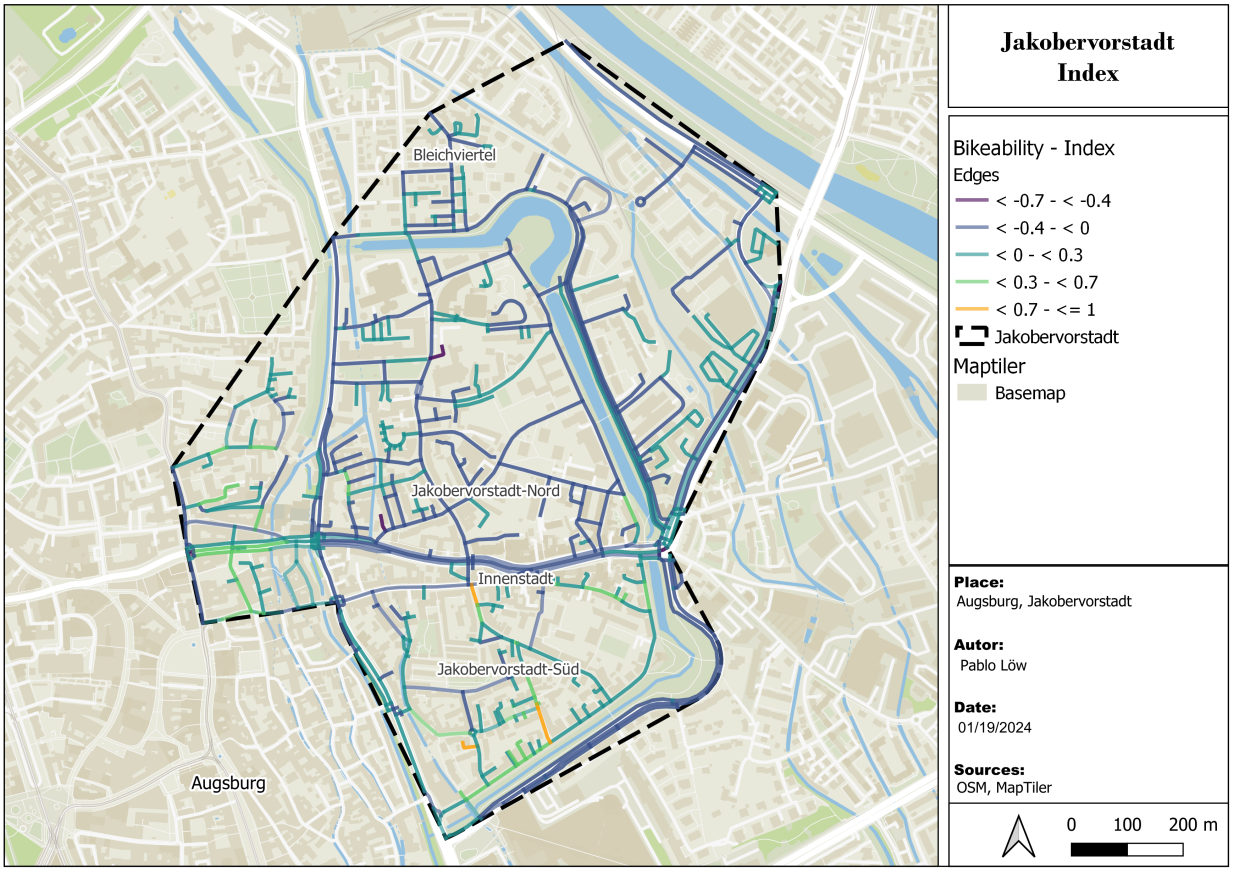

Figure 2: Overview of the region Jakobervorstadt of the case study featuring the street network coloured by the bikeability index

In a network as presented in map 2 the shortest route between two points can be calculated using a default function of the OSMnx package with different weights (real- and felt-length). The two different routes can be seen in map 3. Starting in the south the red route takes the shortest way to a bigger and more even street, because at the starting point all streets have cobblestones. It then follows this street almost until the goal. The green route takes the small streets with cobblestones, which is the more direct way to the goal from south to north. It is hence 40 meters shorter.

4 Discussion

Measuring the roughness via a smartphone attached to the handlebar as a method has its challenging parts. One is that every bicycle is different and in this case study two different ones were used. The accelerometer has a maximum acceleration value that can be measured, due to which a minor error between the different bicycles exists at points with extreme roughness. There are several apps that can save the accelerometer data in CSV files and submit those via email or store them in a

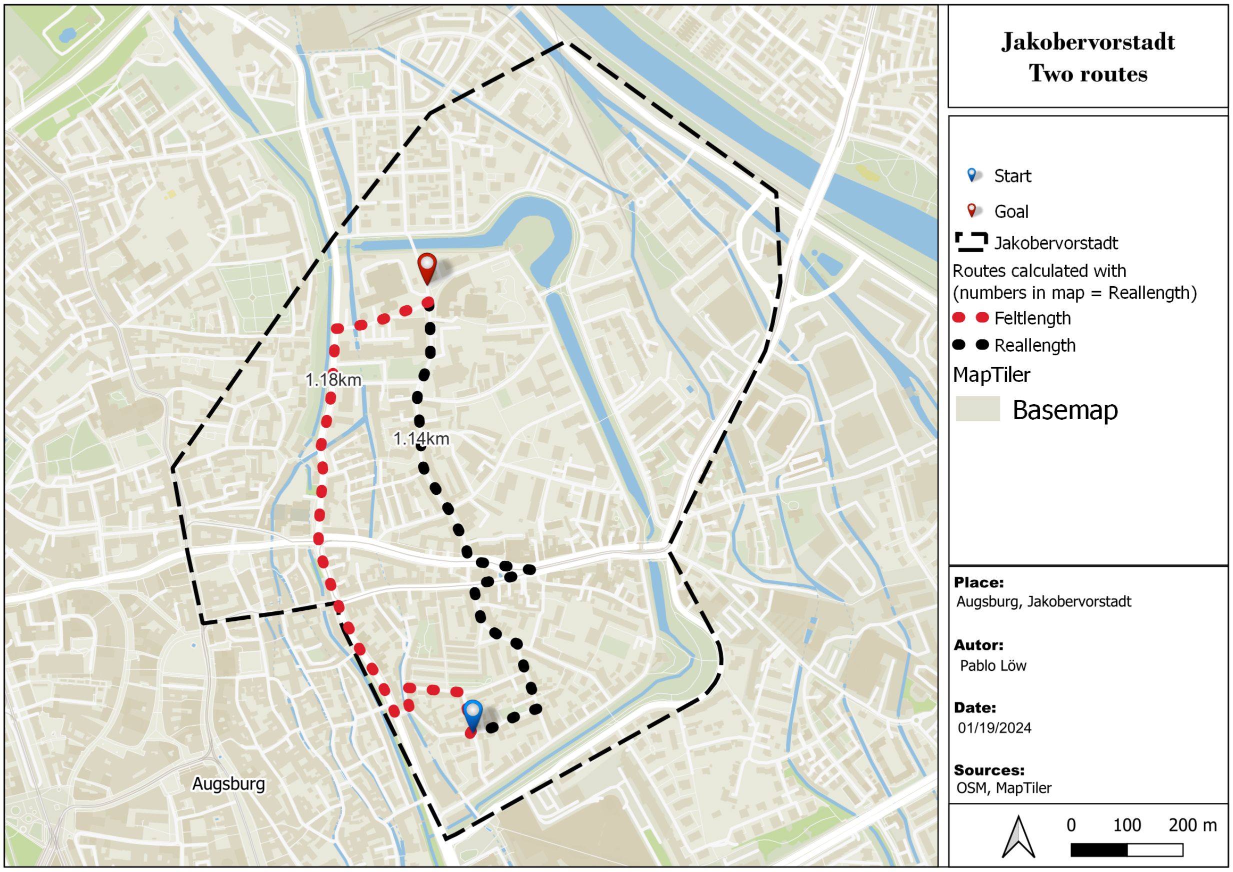

Figure 3: Two different routes from the same start- and end- point. The black one calculated with the real length and the red with the felt length

cloud and share the link. It is an important aspect of this method that via crowdsourcing, way more data for a region can be acquired. Thus, a wider range of bicycles with different behaviour are considered in the creation of the index. The resulting averaging effect can help to minimize the impact of outliers or measuring errors.

Another challenge is the rubber mounting. It is not firm but relatively swingy. It shakes at higher speeds on small disruptions of the street surface, or when the driver changes the grip on the handlebar. Thus, the position of the smartphone can change leading to measuring errors at the Z-axis. That can greatly affect the quality of the measurement. The test driver of this study was aware of that problem and put the smartphone back into the horizontal position whenever necessary.

The two different routes from which one is calculated with the normal edge length as weight and the other with the modified, show that the method successfully captures regions at which the surface roughness is higher and makes this information available for routing. That is interesting when bicycles with no-, or little suspension are used. With these the ride is more enjoyable on an even road surface. The knowledge of the surface roughness along the route is especially relevant for racing- and transport- bicycles.

The method is dependant on the existence and quality of a road network. But because with OSMnx its easy to obtain one for nearly anywhere on the planet that is not a problem in most cases. The quality of OpenStreetMap (OSM) data is usually good especially in places where many people live, as it is crowd sourced (Boeing, 2017; Mooney et al., 2010).

Because the data is stored locally on the smartphone the size of the csv files are not that important. The data can be gathered offline and then uploaded to a server whenever wifi is available. Thus initiatives like OSM could accumulate, process and make the data publicly available. Thus allowing to enhance an entire road network if a public institution decides to implement the method and substitutes webspace for the data.

5 Summary

Even though it already provides useful results future research on the behaviour of different bicycles, mounting tools and positions could lead to a more precise index. Another direction for research could be the optimisation α and β, which can be used to change the impact of the speed on the index and the stretching of the edge length.

The road network exists in most places or can be created by the inhabitants themselves via OSM. Cyclists have their own interest in participating and gathering data because it can improve their options of route finding with the proposed method.

A strength of this approach is that it creates an option. It can be chosen to consider the surface roughness or not when searching for a route, or calculating both and then selecting. The information it provides can be visualized as well in form of, for example, service areas.

6 Biography

Pablo S. Löw is a PhD student at the department of applied geoinformatics of the university of Augsburg. He wrote his master thesis on finding city delineations based on morphological characteristics. He currently pursues his interests in routing options based on different measures and the possibilities accelerometer data gathered via crowd sourcing offer.Jukka M. Krisp is the professor of the department of applied geoinformatics of the university of Augsburg. He is focused on Location Based Services (LBS) Geographic Visualization / Visual Analytics, Spatial Modeling, Geographic Information Systems applications and GIS in ecological network planning.

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