Using schematic maps for visually communicating efficient routes

Stefan Fuest
Institute of Cartography and Geoinformatics
Leibniz University Hannover, Germany
stefan.fuest@ikg.uni-hannover.de

Monika Sester
Institute of Cartography and Geoinformatics
Leibniz University Hannover, Germany
monika.sester@ikg.uni-hannover.de

***Abstract* — Due to an increasing traffic density in urban environments, it is becoming more important for the traffic management to make road users aware of efficient route alternatives to obtain a better distribution of the traffic flow. In this approach, we use schematic maps to visually communicate and recommend routes to the traveler, which are efficient in terms of different traffic-related scenarios. Our methods used to create the maps are based on human perception of space, in order to communicate routes and traffic situations more intuitively.**

***Keywords* — Schematics, route visualization, cartographic generalization, route choice behavior, cognitive maps**

I. INTRODUCTION

As the traffic volume in urban environments increases rapidly, in many cases the existing transport infrastructure is not able to cope with the growing number of individual vehicles any longer. The consequences are–among others–a growing risk of congestion, accidents and air pollution. We may argue that these problems are also caused by a non-optimal distribution of vehicles within the road network. To improve the overall quality of the traffic dynamics, it is important for the traffic management to make road users aware of optimal route alternatives, e.g. to reduce congestion and to make more efficient use of the road network. Maps are a powerful means to visually communicate routes and associated traffic situations. Our idea is to use maps to communicate the efficiency of a route by presenting the route information in a way, how the road user might perceive it when traversing the environment, rather than using a metrically correct representation [1]. Furthermore, our visualization intends to make road users aware of the consequences, the current traffic dynamics might have on the overall traffic situation, while motivating them to re-consider route choice behavior towards a more altruistic behavior.

Research in cognitive psychology suggests that people mentally abstract the geographic space when acquiring knowledge about an environment and communicating route directions to others [2, 3]. In particular, hand-drawn sketch maps provide helpful information to learn which elements of the environment (and the route in particular) are necessary to be emphasized. In contrast to metric maps, sketch maps schematize information, using distortions, simplifications and other generalization techniques while incorporating relevant and omitting irrelevant information [4, 5, 6].

Regarding types of distortions, we can observe some recurring patterns: Intersections, for instance, are usually simplified in a way that the exact angle of the crossing is not preserved, but rather aligned to a right angle [6]. Similarly, slightly curving paths are usually not drawn using their exact shape, but a rather simplified representation, which approximates a straight line; whereas the shape of more distinct curves is being exaggerated [7]. Furthermore, sketch maps distort the length of road segments. That is, because humans may perceive complex, information-rich route segments to be relatively longer, as they cognitively associate a large amount of information with them; and consequently judge these segments to be longer as they are in reality [8]. In addition to simplifying and distorting the structure of the route and the map elements, people use extra information like cardinal directions, arrows and additional landmarks to support the map user during navigation [9].

II. APPROACH

Based on these schematizations commonly observed in hand-drawn sketch maps of geographical spaces, we propose a visualization framework that allows to automatically recommend efficient routes by means of cartographic generalization [10, 11], as well as symbolization. The framework uses a web map environment as an interface for the user to perform a routing and involves two different types of agents: First, the traffic management, which specifies regulations to improve the overall road traffic and therefore directly interferes into the dynamics of the traffic infrastructure; and second, the individual user of the traffic infrastructure (traveler), who intends to travel from one location to another in the most efficient way. The map environment is created using the JavaScript library *Leaflet*, while displaying *Open Street Map* data for the base map.

In the current framework, a routing function provides route recommendations based on a regular routing scenario, and additionally three different environmentally relevant conditions that represent some of the most important challenges the traffic management has to face nowadays: 1) The current traffic density (congestion), 2) the current level of particulate matter (air pollution) and 3) the current risk of accidents [12]. The traffic management can flexibly interfere into the traffic dynamics in case the – under usual circumstances – fastest route would be affected by a temporal disturbance, by recommending a temporarily efficient route. In case of air pollution, for example, the recommended route would avoid areas that exceed a specified threshold value. The route calculation for the regular routing scenario is based on the static, average travel time required to travel along a route under usual conditions. For all other conditions, routes are calculated based on dynamic spatio-temporal data.

Once the routes have been calculated, the geospatial data that is required for the subsequent visualization process will be extracted from the map data. Since we intend to visualize efficient routes, we are primarily interested in vector data showing the routes, as well as the adjacent road network.

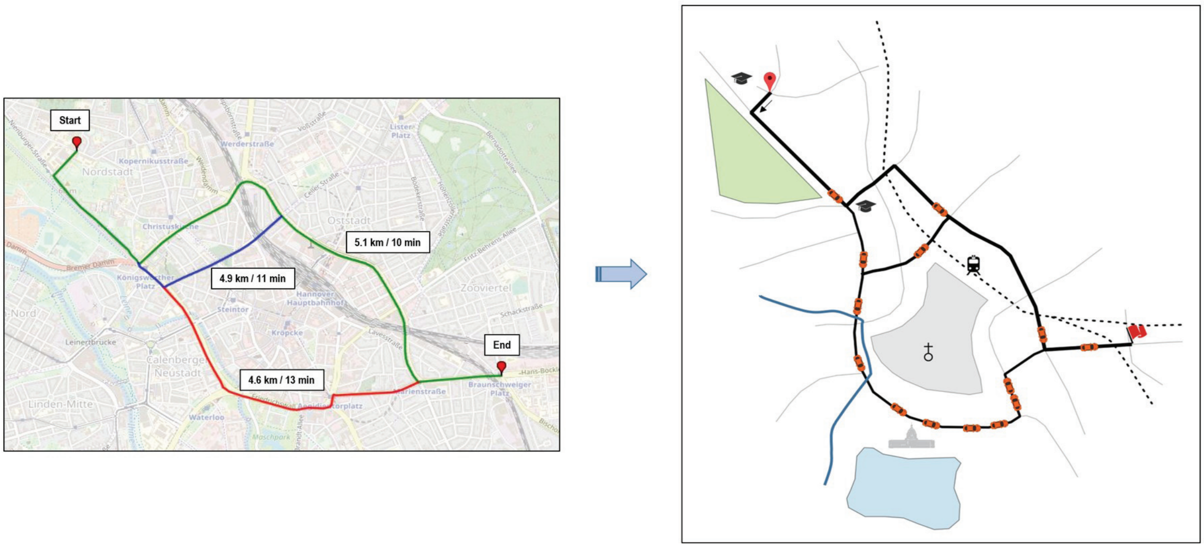

Fig. 1. Selected route options presented on a metric map (left), as compared to our generated visualization using a schematic map (right).

However, we may also extract additional features like object information that could be relevant for being included in a visualization.

Figure 1 shows a potential visualization of a schematic map in case of a *congestion scenario*. Here, the traffic management specified a threshold, so that the traffic density should not exceed a particular level, in order to avoid congestion. Thus, the most efficient route, which should be recommended to the traveler, needs to avoid roads that temporarily exceed the defined threshold for traffic density. Our proposed method is to visually communicate the advantages of a recommended route, by using characteristics of cognitive maps as an input. Similarly, we use cartographic visualization techniques to make travelers aware of the consequences, a temporarily inefficient route may have on the individual journey as well as on the entire traffic situation. The figure shows two types of visualizing routes on a map: The metric map (as commonly used for various routing services) on the left shows all route options, highlighted on a geometrically accurate route map, while using different colors for different routes. Additionally, the entire road network, as well as other geographical objects are integrated in the map, although some of this information might not be relevant for routing. The map further informs the traveler about some characteristics of the routes, including the route length and the currently expected travel time. The green colored line represents the fastest and most efficient route in terms of traffic density.

Therefore, our system recommends this route as the optimal route, although it is not the shortest. The second map on the right shows an example of a potential schematized output map as presented to the traveler using our visualization framework. In the scenario, the traffic management intends to reduce traffic density on various roads within the map area to improve the traffic dynamics. The visualization gives the impression of a higher density and an increased complexity of the non-recommended route.

III. Visualization Operators

We apply the following visualization operators to visually communicate the most efficient route in terms of traffic density to the traveler: As a first step, we perform road network attenuation based on the selection of line features. For this, we extend the idea of *good continuation*, while focusing on several relevant routes within the network [13]. The network is being attenuated based on the relative importance of an individual road. In the example above, we attenuate the road network based on the current traffic density, which means that a road segment is more likely to be retained in the road network, if the traffic density is relatively low. We further distort the length of road segments by using the current traffic density as an input for generalizing road segment length. Here, the idea is that travelers perceive road length depending on the actual travel time associated with traversing the route [8]. That is, if it takes a very long time to drive along a relatively short road due to congestion, we might perceive this road as longer as it is in reality. Similarly, we will judge a long road that we can traverse very quickly and smoothly as relatively shorter [14]. As a further method, we apply line simplification, for which a variation of the Douglas–Peucker Algorithm [15, 16] is used. Here, we further introduce a reversed version of this algorithm for representing non-optimal routes as more complex by adding additional points to the polyline. This leads to a representation that may correspond to the perceived shape of the traveled path, resulting in the recommended route to look easier to traverse than other, non-efficient route options. A more detailed description of some of the algorithmic approaches we use for the automatic visualization process is provided in the here referenced paper [17].

Whereas we primarily intend to generate our visualizations based on generalization approaches, the subsequent symbolization process mainly intends to supplement the visualization results to even more emphasize characteristics that represent the efficiency of a route or the environment. Similar as introduced for cartographic generalization, symbolization operators can depend on temporal attributes. In the map example above, we use car symbols, which represent a predefined traffic density. Thus, a very congested road segment will be symbolized by adding a larger number of symbols to the route visualization.

We further suggest that road segments with a relatively low traffic density at a given time are more relevant for visualization and should preferably be recommended to the traveler. Therefore, we adjust the width of a road segment according to the traffic density data [18]. More specifically, roads with a low density are visualized using a larger width than roads with a higher density. That is, because, from a visual point of view, a wider road segment looks more *important* than a narrow road; and therefore is more likely to be chosen as part of a route alternative.

IV. Conclusion and Outlook

In conclusion, our proposed solution for using schematic maps in the context of visually recommending optimal routes intends to make travelers aware of the necessity to re-consider route choice behavior, due to various factors that can influence the traffic dynamics. To do so, we visualize the traffic infrastructure in a way that the traveler might perceive it while navigating, instead of presenting the accurate structural shape of the road network. Although in some cases we may highly simplify or distort the real shape of the route, the most important point is that the topological relations between the map objects are retained – to ensure that map objects can still be matched with the real-world equivalent when actually traversing the route [1]. In order to avoid confusion, however, it is necessary to inform the road user that the map is visualized in a schematized format - particularly those who are familiar with the road network. Future work on this project will focus on the implementation of algorithms to automate the process of producing schematic maps for different route recommendations and in various traffic situations. Subsequently conducted user studies intend to assess the quality and suitability of the developed visualization methods. They will particularly focus on investigating the effects of using different visualization methods on route choice behavior as compared to established visualizations of route recommendations – in addition to investigating the semantics, people will associate with the different types of visualizations, as well as the general acceptability of the schematic map. Furthermore, it will be examined, if it is more efficient to combine various visualization methods in one representation, or to only use one single method per each representation – to avoid a potential cognitive overload in working memory [19]. In particular, we intend to obtain a representative collection of visualization methods that can serve as a guideline to visually recommend any type of route, under various circumstances.

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