Anchored Metro Maps: Combining Schematic Maps with Geographic Maps for Multi-modal Navigation

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***Abstract*—For conducting navigation tasks in public transportation systems, schematic maps (e.g., metro maps) are the first choice, as they reduce the amount of information to a minimum. On the other hand, for navigation tasks in street networks, classical geographic maps are preferable, as they depict the area as accurately as possible. In this work, we create synergies between both types of maps by laying the metro map over the street map. We call those maps *anchored metro maps*, as we visually attach the metro stations of the metro map to their counterparts on the street map. Currently, we are developing algorithms optimizing the matching between both maps. In future research we plan to use this approach to show that the combination of schematic and geographical maps leads to an improvement for certain navigation tasks.**

***Index Terms*—geographic maps, metro maps**

I. Introduction

The usage of maps is wide-ranging, but certainly the most important application is navigation. Depending on the means of transportation different types of maps serve as helpful tool to figure out a suitable route. As an example take people (e.g., tourists) who explore a city by foot and the metro system. If the next destination is in walking distance, a simple street map of the city is entirely sufficient to find a suitable route. If the destination is further away, the people need to solve two tasks. Firstly, they need to find access points to the metro system that are close to their current location and their destination, respectively. In particular, they need to plan the walk from their current location to the first access point and the walk from the second access point to their destination. Secondly, they need to find a good route through the metro system. This route should comply with short travel times and few switches at stations. Apparently, both tasks are closely interlinked. For the first task a geographic street map is a simple and effective tool. For finding a good route through the metro system a schematic map is the first choice, as it only shows the information necessary for routing. Hence, the question arises how to combine the advantages of both types of maps such that the user can easily perform the entire navigation task.

One possibility of combining schematic and geometric maps is to visualize the process of morphing one map into the other [1]. However, the distortion might become rather strong such that navigation becomes difficult. In this work we answer the question by simply laying a metro map over a geographic street map; see Fig. 1*.

We particularly aim at a schematization of the metro system such that the metro stations of the metro map are closely placed to their counterparts on the street map. In other words, we aim at a small geometric distortion of the schematic map [2]. To ease the description in the following, we use *metro stations* to refer to the depicted stations of the metro map and we use *geo-locations* to refer to their positions on the street map.

Apparently, the applied rules for schematization force some metro stations to be placed further away from their geo-locations than others. To visually associate the metro stations with their geo-locations, we connect the stations with their geo-locations. We call those connectors *anchors* and the resulting map an *anchored metro maps* expressing that the metro map is attached to its geographic representation.

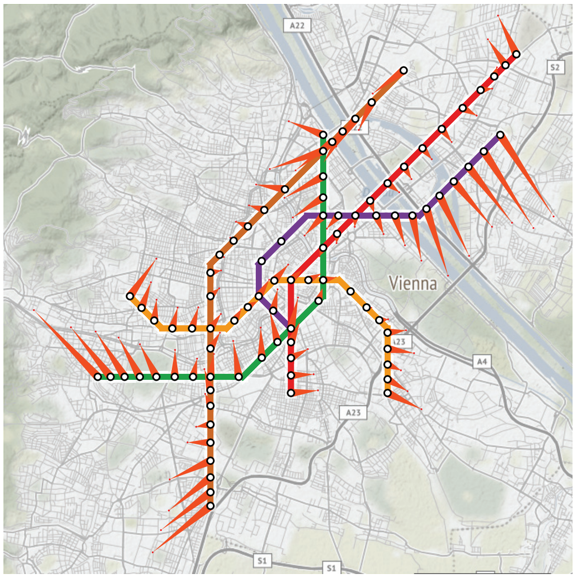
As we carry out in Section II the more general research question behind this concrete problem setting is whether the usability of geographic and schematic maps can be significantly improved for certain tasks by combing both types of maps. In Section III we sketch our current research on this question in general and on anchored metro maps specifically.

II. Research Goals

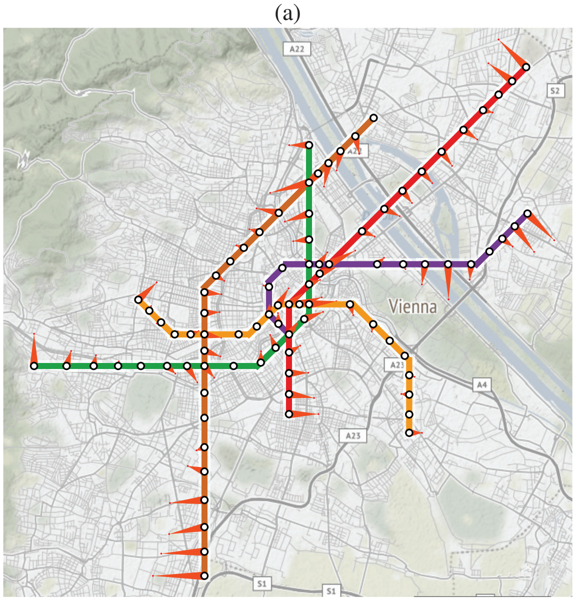
Laying a schematic map over a geographic map is a conceptually simple idea. Still, it is far from clear whether and how this concept actually improves the usability of maps. Depending on the technique the composed map may appear cluttered or lacks a clear visual association between both maps. On the other hand, one can easily imagine examples where the composition of both maps is more than the sum of the single maps. We conjecture that this is also the case for anchored metro maps.

To verify this hypothesis we plan to conduct user studies investigating the performance and accuracy of participants using either anchored metro maps or classic maps. To this end, we need an easy method to create a large variety of such maps for different parameter sets. To obtain comparable results, this particularly requires algorithms that assure guarantees with

*A high-resolution map is found at http://www2.geoinfo.uni-bonn.de/html/anchoredmetromaps/



(a)



(b)

Fig. 1: Anchored metro map of Vienna. Anchors are visualized as orange rectangles. The metro map layout has been produced by the approach of Nöllenburg and Wolff [4] and modified with our algorithm. The edges have been (a) uniformly and (b) non-uniformly scaled. Map tiles by Stamen Design, under CC BY 3.0. Data by OpenStreetMap, under ODbL.

respect to pre-defined design rules. This particularly allows us to investigate the impact of single design rules switching them on and off. For identifying these design rules and to fine-tune our algorithms we plan to do expert interviews, in which we discuss generated drafts of anchored metro maps.

III. Algorithmic Approach

Currently, we are developing algorithmic tools for generating anchored metro maps. A rather straightforward approach is to compose an existing street map with an existing metro map by scaling and translating the metro map fitting the metro map onto the street map. However, this might yield large distances between metro stations and their geo-locations even if we do this in a mathematically optimal way; see Fig. 1a. To overcome this problem, we propose to additionally admit changing the relative lengths of the edges, while keeping their direction unchanged. Hence, while a simple approach scales all edges of the metro map uniformly, our approach distorts the metro map by scaling the edges individually preserving the topology of the map; see Fig. 1b.

Following ideas by Nöllenburg and Wolff [4], whose approach creates octilinear metro maps, we utilize mathematical programming to obtain a general tool that both yield solutions with mathematical guarantees and can be adapted easily. This provides us with the possibility of integrating design rules both as hard and soft constraints. For example, as hard constraint we require that no edge crossings are introduced. As soft constraint we minimize the overall displacement of the stations with respect to their geo-locations. Since the layout of the map is pre-computed, we can use simple linear constraints preserving the topology of the metro network. Further, we minimize the sum of the euclidean distances between stations and their geo-location obtaining a quadratic objective. As a post-processing step we utilize a dynamic programming approach (conceptually similar to [3]) to fine-tune the positions of the stations that do not lie on crossings.

We have implemented prototypical versions of these algorithms. Initial experiments on the metro system of Vienna show that the displacement is relatively small; see Fig. 1. Although the results are promising, we see great potential for improvement by elaborating on the quadratic programming formulation. For example, anchors should not cross metro lines or run along metro lines. Interviews with experts shall help to identify further improvements.

IV. Conclusion

We sketched a simple approach for combining schematic metro maps with geographic street maps. Currently, we are exploring further extensions and optimizations. We think that with these improvements we are ready to verify our hypothesis that anchored maps improve the performance of users in navigation tasks. Finally, we note that our algorithms can be used within a human-in-the-loop process to support designers in interactively creating metro maps with small geometric distortion.

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