An Automated Method for Circular-Arc Metro Maps

Thomas C. van Dijk*, Arthur van Goethem†, Jan-Henrik Haunert‡, Wouter Meulemans† and Bettina Speckmann†
*Universität Würzburg, Germany. Email: thomas.van.dijk@uni-wuerzburg.de
†TU Eindhoven, The Netherlands. Email: {a.i.v.goethem,w.meulemans,b.speckmann}@tue.nl
‡Universität Osnabrück, Germany. Email: janhenrik.haunert@uni-osnabrueck.de

I. INTRODUCTION

Metro maps are frequently depicted schematically using simple geometries (e.g. octilinear lines or simple curves), to increase legibility of the primary information: the stations and their connections. Automated methods for metro-map schematization have focused on straight-line representations, e.g. [1], [2]; the only exception is [3]. Some recent approaches schematize cartographic shapes with straight lines [4] or curves [5]. However, these methods are typically unsuitable for metro maps as they do not handle high-degree vertices well. We present an algorithm to create metro maps using circular arcs. We steer the geometric similarity of the resulting lines with the (distorted) input map by controlling the number of arcs.

II. SCHEMATIZATION ALGORITHM

Following the approach of Van Goethem *et al.* [5], who schematize territorial outlines, our algorithm iteratively replaces two arcs by a single arc until a user-set number of arcs is reached. As the requirements for metro maps differ from territorial outlines, we change the replacement strategy and add two preprocessing steps.

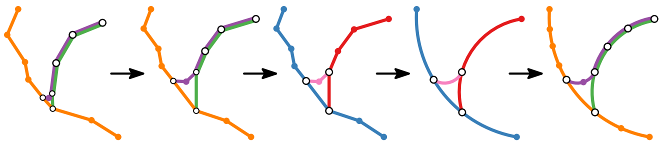

Fig. 1. Geographic input, deformation, strokes, schematization, rendering.

Deformation. First we deform the network to more evenly distribute network density. This improves readability [6] and helps the schematization. To ensure the geometry resembles the geography, we use minimum-distortion focus maps [7]. We set the desired scale factor of a station v to $1 + c \cdot k_v$, where c is a constant and k_v is the number of stations within a given distance of v.

Strokes. We then partition the network into strokes (simple paths and cycles): replacements operate only within a stroke. First we aggregate adjacent metro connections having the same set of metro lines into preliminary strokes. If a single metro line has branches, we aggregate based on the smallest angular change. This strategy allows for continuity at interchanges for a single line (or group of lines). Then we further aggregate these preliminary strokes, based on angular deviation, to allow for more schematization.

Replacement. Van Goethem *et al.* use area-equivalent replacements [5]. We choose different replacement arcs, as enclosed regions are of little relevance for metro maps. We want the replacement arc to resemble the deformed geographic situation well, as quantified by the Fréchet distance [8]. To find a good arc, we test a discrete set of candidates.

High-degree vertices. Metro maps often have many high-degree vertices (interchanges). Hence, unlike Van Goethem *et al.* [5], we cannot simply keep the interchanges in fixed locations: this would be too rigid. We allow the replacement of two arcs that meet at a high-degree vertex. For a degree-3 vertex the third connection is extended to touch the replacement arc. For higher-degree vertices, the replacement arc is constrained to pass *near* the original location: we can admit some leeway by drawing interchanges as the minimum-enclosing disk of the relevant lines.

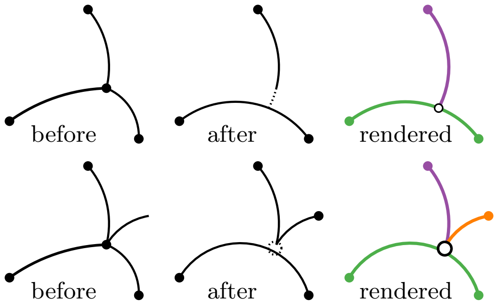

Fig. 2. Replacement with a degree-3 vertex (top) yields an extension (dashed). Replacement with a degree-4 vertex stays near its original location.

Future work. The current replacement operations do not yet take into account the distance in between stations and in between different lines. Future work might investigate the trade off between ensuring these distances and maintaining flexibility. Similarly, a trade-off between continuity at high-degree and low-degree vertices exists.

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REFERENCES

[1] D. Merrick and J. Gudmundsson, "Path simplification for metro map layout," in *Proc. 14th Graph Drawing*, 2006, pp. 258–269, LNCS 4372.

[2] M. Nöllenburg and A. Wolff, "A mixed-integer program for drawing high-quality metro maps," in *Proc. 13th Graph Drawing*, 2005, pp. 321–333, LNCS 3843.

[3] M. Fink, H. Haverkort, M. Nöllenburg, M. Roberts, J. Schuhmann, and A. Wolff, "Drawing metro maps using bézier curves," in *Proc. 20th Graph Drawing*, 2013, pp. 463–474, LNCS 7704.

[4] K. Buchin, W. Meulemans, and B. Speckmann, "A new method for subdivision simplification with applications to urban-area generalization," in *Proc. 19th ACM SIGSPATIAL GIS*, 2011, pp. 261–270.

[5] A. van Goethem, W. Meulemans, B. Speckmann, and J. Wood, "Exploring curved schematization," in *Proc. 7th PacificVis*, 2014, to appear.

[6] D. Merrick and J. Gudmundsson, "Increasing the readability of graph drawings with centrality-based scaling," in *Proc. 2006 Asia-Pacific Symp. Info. Vis.*, 2006, pp. 67–76.

[7] J.-H. Haunert and L. Sering, "Drawing road networks with focus regions," *IEEE TVCG*, vol. 17, no. 12, pp. 2555–2562, 2011.

[8] G. Rote, "Computing the Fréchet distance between piecewise smooth curves," *CGTA*, vol. 37, no. 3, pp. 162–174, 2007.

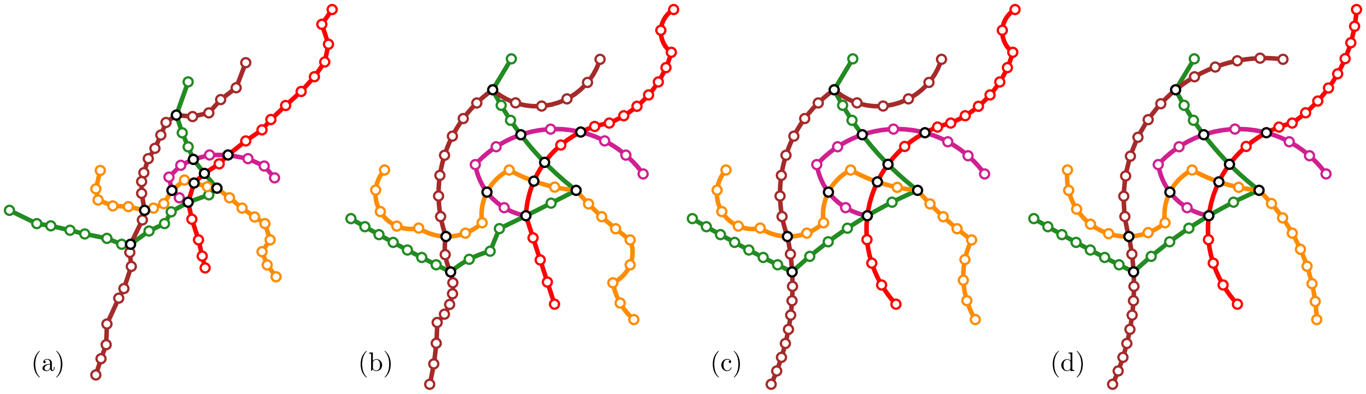

Fig. 3. (a) Geographically accurate metro network of Vienna. (b-d) Schematized metro maps using 24, 18, and 14 circular arcs.

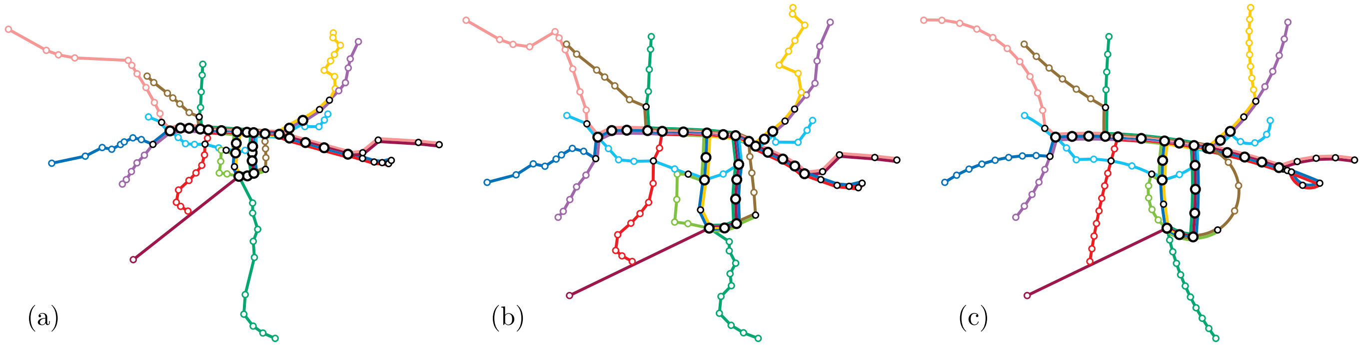

Fig. 4. (a) Geographically accurate map of Karlsruhe transit network. (b-c) Schematized metro maps using 27 and 19 circular arcs.

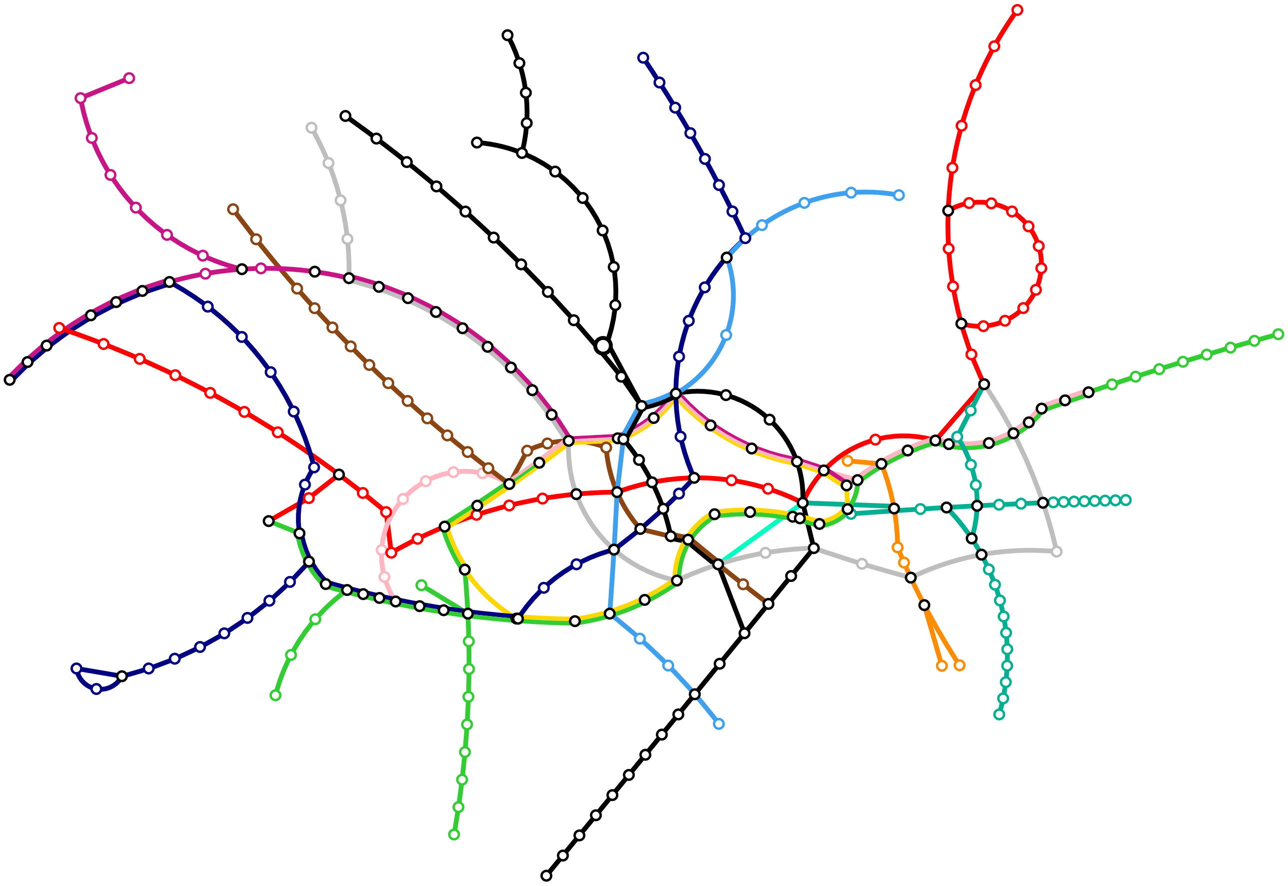

Fig. 5. Schematized metro map of London using 81 circular arcs.