Mixed Metro Maps with User-Specified Motifs*

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Abstract. In this poster, we propose an approach to generalize mixed metro map layouts with user-defined shapes for route-finding and advertisement purposes. In a mixed layout, specific lines are arranged in an iconic shape, and the remaining are in octilinear styles. The shape is expected to be recognizable, while the layout still fulfilling the classical octilinear design criteria for metro maps. The approach is in three steps, where we first search for the best fitting edge segment that approximates the guide shape and utilize least squares optimization to synthesize the layout automatically.

Keywords: Metro maps · least squares optimization · shape-preserving Dijkstra algorithm · Fréchet distance.

1 Introduction

Metro maps are schematic representations of a metro network in order to facilitate effective route findings. Creating such maps manually is a challenging task, and thus several automatic approaches have been developed in the last two decades [10]. Most approaches aim for a single style, e.g., octolinear layouts (based on a set of slopes of multiples of 45°) [7, 8] or curvilinear layouts [3] (lines represented as smooth continuous curves). However, handcrafted metro maps often employ more than one style in a single map, to emphasize specific lines in the system, where some parts are arranged in an iconic shape and some in an octolinear style. The official Moscow metro map with its characteristic circles is a typical example [6]. Moreover, such maps could be used for advertising purposes or special events [11].

In this poster, we present an approach to generalize a mixed layout problem with a user-defined *guide shape*, represented as a polyline, as input. To guarantee the visual quality, the guide shape should be recognizable in the final layout, while the layout still fulfills the classical octolinear design criteria [7].

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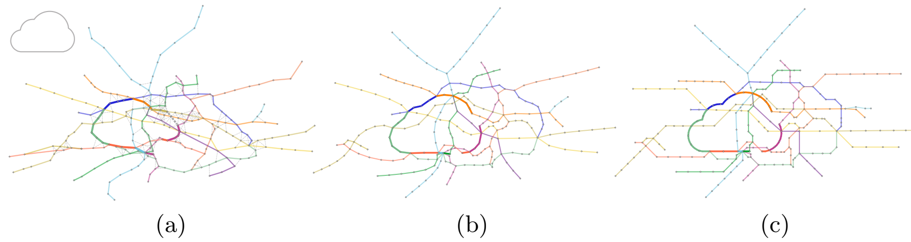

Fig. 1. Paris metro map, consisting of 236 stations and 268 edges. The layout is created with a cloud-shaped guide. (a) Geographically accurate layout with a potential path P highlighted. The input guide shape is shown on the top left. (b) The smooth layout and (c) the mixed layout with smooth edges highlighted.

2 Method

In our approach, we take a metro graph $G = (V, E)$ with geographic coordinates and a user-defined (open or closed) polyline L as input. This line $L = [l_0, l_1, \ldots, l_n]$ with line segments (l_i, l_{i+1}) serves as the user-specified guide shape for our mixed layout. Our approach is in three steps. First, the approach searches for the path that is the best representative of the user-defined guide shape. Then, we deform the metro graph to a smooth and finally to a mixed layout following the aforementioned design criteria.

To find a good alignment, we adapt the shape-preserving Dijkstra algorithm [5], which allows us to iteratively find potential paths $P = (v_i, v_j, ...)$ in G that are similar to the input guide shape L (Figure 1(a)). In contrast to the original approach [5, 4], we quantify the difference between the path P and L using the Direction-Based Fréchet Distance [1]. After finding a good path P in the metro graph, we scale the guide shape and align the bounding boxes of the found path and the input guide shape for better deformation.

Our deformation is inspired by the approach of Wang et al. [9]. We first create a smooth layout (Figure 1(b)), and then the mixed layout (Figure 1(c)). Here, we optimize four constraints $\Omega = w_l\Omega_l + w_a\Omega_a + w_p\Omega_p + w_c\Omega_c$. Ω_l enforces uniform edge lengths, Ω_a maximizes angular resolutions, and Ω_p minimizes the distance of the position of a metro station $v \in V$ to its geographical location. In addition, Ω_c forces the layout to approximate the guide shape. This constraint pushes a station $v_i \in V$ in the direction of the guide shape L, if v_i is a close candidate that should be selected for shape approximation. More precisely, v_i will be moved toward the direction of point p_i, which is a projected point of v_i on the polyline L after bounding box alignment. To create a clear layout, we approximate each small segment of the guide shape with one single metro edge and, therefore, apply Ω_c only to a subset of the vertices. Let v_i' be a copy of v_i, which has been rotated around p_i by 180°. To determine if the constraint Ω_c should be applied to the vertex $v_i \in V$, we check if any edge $e \in E$ is located between v_i and its projection p_i or between v_i' and p_i. If no such edge is found, the constraint Ω_c is added for this vertex.

To create the mixed layout, we differentiate between two types of edges. Smooth edges (highlighted in Figure 1(c)) approximate the shape and should align to a section of the guide shape L. The remaining edges are octolinear edges, which have to be drawn with an octolinear slope. We determine if an edge $(v_i, v_j) \in E$ is a smooth edge or not by checking if another edge is located between the vertices v_i and v_j and the guide shape L, as we do in the smoothing step. Similar to the smoothing step, we again create the mixed layout using the least squares optimization [9].

3 Results

Our approach creates visually pleasing and interesting results. The tested shapes are embedded well as shown in Figure 1(c). Note that in our results, the guide shape is not approximated by a single connected line but multiple line segments in the metro system. Following the Gestalt Laws (Law of Closure, Law of Prägnanz) [2], we confirm that even paths with multiple discontinuities (resulting from the topology of the metro system) can be perceived and recognized by humans. In our experiments, the relative positions of vertices in the metro graph are not changed and no stations are located too close to another edge or station – making the final layout not only visually interesting but also usable for navigation purposes.

References

1. de Berg, M., Cook, A.F.: Go with the flow: The direction-based Fréchet distance of polygonal curves. In: Theory and Practice of Algorithms in (Computer) Systems (TAPAS'11). LNCS, vol. 6595, pp. 81–91. Springer (2011). https://doi.org/10.1007/978-3-642-19754-3_10
2. Ellis, W.D.: A source book of Gestalt psychology. Routledge (2013). https://doi.org/10.1037/11496-000
3. Fink, M., Haverkort, H., Nöllenburg, M., Roberts, M., Schuhmann, J., Wolff, A.: Drawing metro maps using Bézier curves. In: Graph Drawing (GD'12). LNCS, vol. 7704, pp. 463–474. Springer (2012). https://doi.org/10.1007/978-3-642-36763-2_41
4. Funke, S., Schirrmeister, R., Skilevic, S., Storandt, S.: Compass-based navigation in street networks. In: Web and Wireless Geographical Information Systems (W2GIS'15). LNCS, vol. 9080, pp. 71–88. Springer (2015). https://doi.org/10.1007/978-3-319-18251-3_5
5. Funke, S., Storandt, S.: Path shapes: an alternative method for map matching and fully autonomous self-localization. In: Advances in Geographic Information Systems (SIGSPATIAL'11). pp. 319–328. ACM (2011). https://doi.org/10.1145/2093973.2094016
6. Moskovsky Metropoliten: Moscow metro map & central circle (2019), https://mosmetro.ru/mcc/moscow-central-circle/, accessed 2021-03-08

7. Nöllenburg, M., Wolff, A.: Drawing and labeling high-quality metro maps by mixed-integer programming. IEEE Transactions on Visualization and Computer Graphics **17**(5), 626–641 (2010). https://doi.org/10.1109/TVCG.2010.81
8. Onda, M., Moriguchi, M., Imai, K.: Automatic drawing for Tokyo metro map. In: European Workshop on Computational Geometry (EuroCG'18). pp. 62:1–62:6 (2018)
9. Wang, Y.S., Chi, M.T.: Focus+context metro maps. IEEE Transactions on Visualization and Computer Graphics **17**(12), 2528–2535 (2011). https://doi.org/10.1109/TVCG.2011.205
10. Wu, H.Y., Niedermann, B., Takahashi, S., Roberts, M.J., Nöllenburg, M.: A survey on transit map layout from design, machine, and human perspectives. Computer Graphics Forum (Special Issue of EuroVis 2020) **39**(3) (June 2020). https://doi.org/10.1111/cgf.14030
11. ZERO PER ZERO: City railway system (2021), https://www.zeroperzero.com/city-railway-system, accessed 2021-08-25