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Quantitative Line Glyphs to Visualize Multivariate Geometric Properties in Multi-scale Spatial data

Daria Hollenstein [a], Stefan Eberlein [a,*], Susanne Bleisch [a]

[a] *FHNW University of Applied Sciences and Arts Northwestern Switzerland, Institute Geomatics, Muttenz, Switzerland, daria.hollenstein@fhnw.ch, stefan.eberlein@fhnw.ch, susanne.bleisch@fhnw.ch*

* Corresponding author

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Abstract:

Large differences in scale between the smallest items of interest and the full extent of data at focus pose challenges in the visualization of spatial data. Multivariate attributes further complicate the display of such information with the added challenge of representing multiple attributes simultaneously in an easily interpretable way. We introduce quantitative line glyphs to visualize multivariate attributes in visualizations of multi-scale geospatial data (Fig. 1). Their design is motivated by its application to the visualization of pavement roughness characteristics in the context of barrier-free routing and accessible urban planning. In barrier-free routing, structures of interest vary in size or amplitude from meters down to millimetres, while the length of the route may be 100 m or more. The need to visualize spatial structural information that spans several levels of scale is shared with other fields, e.g. biology (Cakmak et al. 2021). In the context of geospatial data, principles of cartographic generalization and abstraction are commonly applied to deal with a restricted display space and multi-scale information (Viola and Isenberg 2017; Cakmak et al. 2021). For our line glyph design, we draw upon such concepts to create dense, data-related glyphs which generalize to different view scales and work for 1D- (route representation) as well as 2D-visualizations (map representation). We combine the mapping of numeric attributes mostly to the visual variable length with the use of visual metaphors for surface profiles (Fig. 2). We map more than one attribute to each glyph element to create a condensed and generalized image of the underlying data. Visual metaphors and generalization are combined in other (linear) glyph designs to varying degrees (Chernoff 1973; Pickett and Grinstein 1988; Wittenbrink et al. 1996; Ware 2009; Hlawatsch et al., 2011; Li et al. 2015; Kovalerchuk 2018, Cultip and Kovalerchuck 2023). However, giving up one-to-one mapping between data attributes and glyph components runs contrary to existing glyph design principles (Ware et al. 2009) and evidence on the effectiveness of similar glyph designs is limited (Fuchs et al. 2017). To evaluate the proposed line glyph, we used controlled test settings to establish how well participants can read the mentioned visualization at different scales and compared to a base line visualization that maintains one-to-one mapping. We measure value estimation error, correctness of rank order and time spent solving tasks for single attribute reading and synoptic tasks in an experiment with 26 participants.

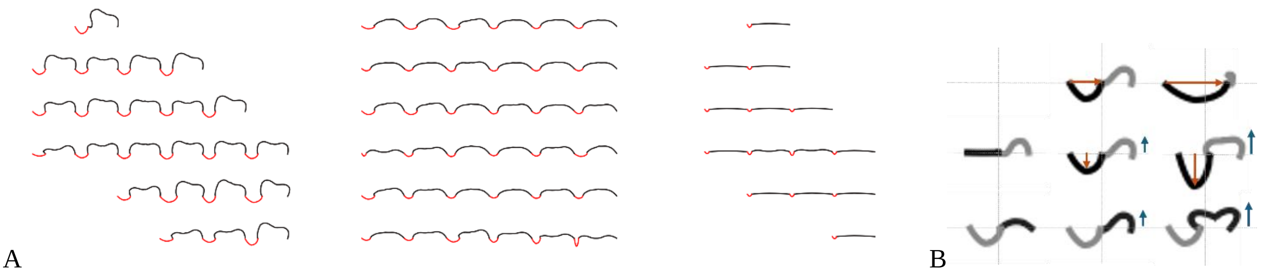

Figure 1: A) Quantitative line glyph. A pictograph-like glyph for continuous mapping of numeric data to gap width and depth (red), amplitude and curvature (black) of glyphs to visualize multiple surface roughness attributes. B) Line glyph design: In every row, a different data dimension is increased from left to right and the corresponding glyph component is highlightet in black (top: length of the left wave segment, middle: amplitude of the left wave segment, bottom: waviness along the right wave segment, blue arrow: amplitude of right wave segment).

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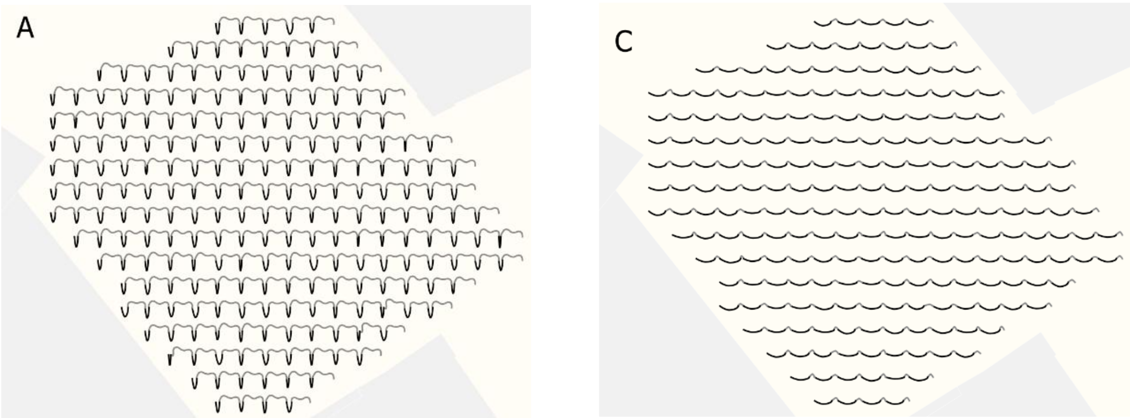

Figure 2: Examples of line glyph maps based on synthetic data generated for the user study. Each glyph covers 1 m².

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