Diagrammatic Metro Maps: Navigational Problems and their Detection and Remediation

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Abstract. The diagrammatic map format is very widely used to represent the routes and services available to passengers of metro rail systems. Despite being extensively used for many decades, this cartographic format has only recently been subject to systematic theoretical and empirical research. There are still large unknowns in the field. This doctoral research project addresses one aspect. It seeks to characterise aspects of a metro map—other than the overall layout—that affect the usability of the map. In particular, it examines colour coding, and navigational hazards that may be produced by inadequately designed transfer points, junctions, and branches. In its second phase, the project will endeavour to utilise this empirical information in the development of software for the automated detection and remediation of such navigational problems in metro maps.

Keywords: Metro Maps, Colour Coding, Navigational Hazard, New York City Subway, Usability Testing, Automated Design.

1 Introduction

Topic. This research aims to characterise navigational problems in diagrammatic maps of metro rail networks, and to develop software tools to detect and, ultimately, fix those problems. The research is primarily in the field of computing but draws on other disciplines, namely psychology, graphic design, and information design for public transport.

Research gap (1): Usability. Metro maps are traditionally created in an artisanal manner without psychological theory or empirical studies of usability. Recently, the notion of evidence-based design of metro maps has emerged, combining psychological models of map cognition with empirical studies of map features and objective measures of usability. Systematic investigation of metro maps by scientific principles is comparatively recent (Guo, 2011). The main results yielded by contemporary usability studies (summarised by Roberts, 2014) are: that objective and subjective evaluations of usability are uncorrelated; that layout affects journey planning; that Beck's octilinear layout is not a 'gold standard' for map layout in all cities, and that instead a framework of more general principles for map layout can be identified, involving the simplicity, coherence, and harmony of line trajectories, and the balance and topographicity of the map layout. Which aspects of a map have the most impact on objective usability is an open question for empirical research. Factors likely to influence usability are: overall layout; colour coding; symbolism and layout of transfer stations; symbolism of non-transfer stations; junction layout; and positioning and typography of labels. What these investigations lack so far is a consideration of the ‘micro-design’ of localised features such as transfers and junctions, as opposed to the ‘macro-design’ of layout.

Research gap (2): Automated design. In parallel with research on map usability, the past fifteen years have seen progress on automated map design. Three main methods of automatically laying out metro maps have been proposed (see Wolff’s (2007) review). Stott & Rodgers (2004) employed a hill-climbing multi-criteria optimization, which is flexible and lets us experiment with different selections of criteria and weightings. Hong (2006) proposed a force-directed model, which is well established for pure diagrams but does not naturally lend itself to diagrams coupled to an underlying geography. Nöllenburg and Wolff (2006) used a mixed-integer programming (MIP) method, a general-purpose global optimisation procedure. A fourth can be noted: Anand et al.’s (2007) simulated annealing method. This work has so far been dominated by the problem of laying out the map, not localized design features. It has also lacked input from cognitive theories that have begun to emerge from the empirical work on usability.

Research Question. The research questions in my doctoral project are: 1) What are the major factors—besides layout—that affect usability in metro maps, and how can we characterise them with reference to psychological models of map reading? 2) How can hazards arising from those factors be algorithmically detected and rectified?

Approach so far. Guided by an outline psychological model of map reading, I made an empirical study of the effect of colour-coding and local navigational hazards in the NYC subway map. This used experimental variants of the official map, and 300 paid volunteers recruited through Mechanical Turk. The first analysis (Lloyd et al., 2018) reports on colour coding. Further phases in hand, on journey planning and navigational hazards, will yield information on features in maps that lead to misnavigation.

2 Work that has been completed

The first analysis established that, as predicted, the colour-coding of metro maps by individual route improves the accuracy with which a map user can trace a route through the map. Also, that local navigational hazards can have a major effect on the usability, and interact with the effect of

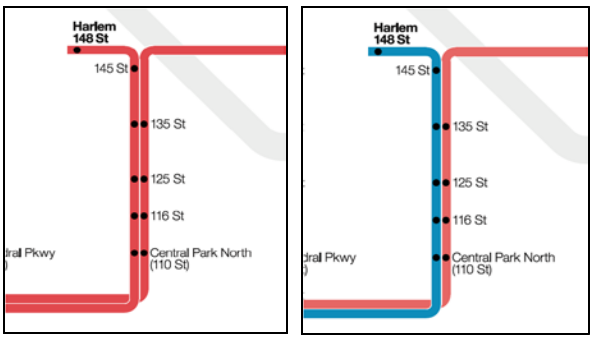

Figure 1 Trunk and route colour versions: where route-tracing ‘slips’

colour coding. Certain specific forms of transfer symbolism and junction layout have been shown to mislead users. Fig. 1 shows a simple case labelled 'Slip F (Flip)': in the trunk coloured map, more than in the route-coloured one, users are more likely to 'slip' between routes where the route lines 'flip'. Full details are given by Lloyd et al. (2018). Where journey planning involves complex cognition, however, the effect is apparently reversed as the clutter of the route colours impacts the cognitive load.

3 Going forwards

Expected contributions of the research. From the first part of this research project, I hope to get new information about hazards in the design of diagrammatic metro maps, which will be of use to map designers and prove useful to developers of automated design software. From the second part, I hope eventually to have a software tool that would work as a 'map checker' (by analogy with spell checkers and grammar checkers), scanning a diagrammatic map and reporting on parts that are recognisably hazardous.

Current problem. A key problem is to find generalisable algorithms for recognising navigational hazards, such as misleading transfers. The first approach will involve *ad hoc* methods for each hazard in a vector graphic. General-purpose recognition tools such as neural nets work with raster images but do not lend themselves to vector images.

References

Guo, Z.: Mind the map! The impact of transit maps on path choice in public transit. Transportation Research Part A 45, 625-639 (2011). doi:10.1016/j.tra.2011.04.001

Hong, S-H, Merrick, D., and Nascimento, H.A.D.: Automatic visualisation of metro maps, Journal of Visual Languages & Computing, 17(3):203–224 (2006).

Lloyd, P.B., Rodgers, P., Roberts, P.J.: Metro Map Colour-Coding: Effect on Usability in Route Tracing. Accepted for Diagrams 2018 Main Track, Edinburgh (2018).

Nöllenburg, M., Wolff, A.: A mixed-integer program for drawing high-quality metro maps, in: Proceedings of the 13th International Symposium on Graph Drawing (GD'05), published in Lecture Notes on Computer Science 3843, 321–333, Springer-Verlag (2006).

Roberts, M.J.: Schematic maps in the laboratory. In: First International Schematic Mapping Workshop University of Essex, 2nd–3rd April 2014. , last accessed 2017/11/29 (2014)

Stott, J.M., Rodgers, P.: Metro Map Layout Using Multicriteria Optimization. In: Proceedings of 8th International Conference on Information Visualisation (IV04), IEEE, 14th-16th July 2004. 355-362 (2004). doi:10.1109/IV.2004.1320168

Wolff, A.: Drawing Subway Maps: A Survey. Informatik—Forschung und Entwicklung 22, 23-44 (2007). doi:10.1007/s00450-007-0036-y