Designing maps & visualizations for mobile devices: A collaborative research agenda

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Introduction: More maps are viewed on mobile devices today than in any other format, media, or platform (Abraham 2019). Yet, much of the cartographic canon we teach and practice was established for the design of printed maps, where ink is immutable but precise, map sheets are big but foldable or bound in an atlas volume, and map design bends to the mapmakers' intentions rather than the map users' individual needs and context. *Mobile first* describes an approach to user experience (UX) design, map-based or otherwise, that is optimized for the technological constraints of mobile devices, such as smartphones, tablets, smart watches, and heads-up displays (Ricker and Roth 2018). Mobile-first design serves as the anchor point for a broader *responsive design* strategy that dynamically adapts the content, layout, and styling from the more constrained, mobile use case to more flexible, non-mobile use cases (Marcotte 2010). Accordingly, mobile first is a design philosophy that considers the most constrained user experience before others (Roth 2019) and, therefore, aligns with tenets of the broader *inclusive design* movement that prioritizes support for marginalized users and use cases throughout the design process (D'Ignazio and Klein 2020). We present the collective research agenda for mobile-first, inclusive, and responsive cartographic design published in the special issue of the *Journal of Location Based Services* on user experience design for mobile cartography (see Roth et al. forthcoming).

Design Space: The research agenda presented here is one of a trio resulting from a collective, multi-stage ICA joint commission initiative on user experience design for mobile cartography (see https://use.icaci.org/user-experience-design-for-mobile-cartography-setting-the-agenda/ for details). Compared to the partner research agendas on mobile map cognition (see Griffin et al. forthcoming) and mobile technology (see Huang et al. forthcoming), our research agenda explicitly focuses on challenges regarding *design*. Accordingly, we began our discussions by establishing a partial design space for mobile-first and responsive maps and visualizations. Specifically, we explored five dimensions (i.e., sets of design decisions) of the cartographic design space requiring future research for adaptation to mobile: (1) scale and generalization, (2) projections, (3) symbolization and visual hierarchy, (4) toponymy and typography, and (5) user interaction. We then situated these design considerations within the constraints, affordances, and consequences of mobile technology in order to think through open questions for adapting these design decisions for the mobile context (Figure 1).
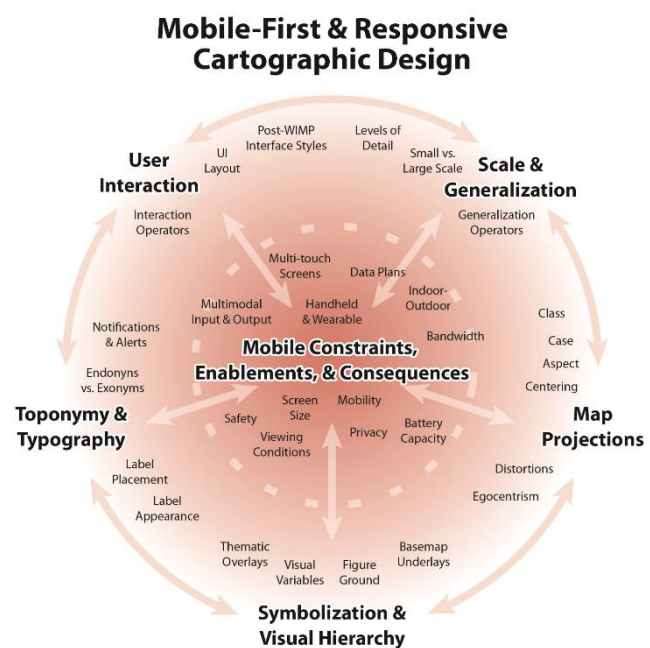

Figure 1: A partial design space for mobile-first and responsive cartographic design. Redrawn from Roth et al. (forthcoming)

Research Agenda: We present 20 open research questions facing mobile-first and responsive cartography and visualization (Table 1). Research challenges are organized according to five dimensions of the Figure 1 design space, but many challenges span multiple dimensions. The agenda crosses and organizes a range of research foci in cartography and visualization—such as augmented/mixed reality, indoor/outdoor mapping, egocentrism, focus+context techniques, energy-aware design, glanceable visualization, visual storytelling, UI/UX design, multi-modal and embodied interaction, and inclusive design. In the presentation, we will discuss and provide examples for the identified 20 challenges, centering conceptual, practical, and critical questions for mobile-first and responsive cartographic design.

1	**Mobile-first and Responsive Scale and Generalization**
1.1	Should generalization be speed- or cost-dependent rather than scale-dependent for mobile-first cartography and visualization?
1.2	How should mobile maps and visualizations be generalized at the vista scale?
1.3	How do we consistently generalize mobile maps and visualizations for both indoor and outdoor use?
1.4	What level of detail is appropriate for augmented and mixed reality on mobile devices?
2	**Mobile-first and Responsive Projections**
2.1	What is the efficacy of egocentric designs and oblique projections?
2.2	Should projection selection adapt to device aspect ratio, space efficiency, orientation, and other dimensions of the mobile use context?
2.3	What focus+context visualization techniques are useful for mobile first cartographic design?
3	**Mobile-first and Responsive Symbolization and Visual Hierarchy**
3.1	How can mobile-first symbolization be energy-aware?
3.2	What is the role of imagery and realism in the mobile-first visual hierarchy?
3.3	How can mobile map icons be crosscultural, plural, and inclusive?
3.4	What is mobile-first thematic map design?
3.5	How can non-visual, multimodal symbolization and interaction be used in mobile maps?
4	**Mobile-first and Responsive Toponymy and Typography**
4.1	How can mobile map labels be cross-cultural, plural, and inclusive?
4.2	How should labels be placed on mobile maps and visualizations?
4.3	Can labeling adapt to the user's gaze?
4.4	What role do text-based alerts and notifications play in mobile map and visualization design?
5	**Mobile-first and Responsive User Interaction**
5.1	How do interaction operators and interaction strategies differ between mobile and non-mobile maps and visualizations?
5.2	What is the efficacy of emerging user interface (UI) solutions for mobile interaction operators?
5.3	What mobile interaction operators can be performed through spatial, tangible and embodied interaction?
5.4	What new constraints, enablements, and consequences are possible with emergent mobile platforms?

Table 1: Research challenges for mobile-first and responsive cartographic design after Roth et al.(forthcoming).

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