Towards Designing Better Map Interfaces for the Mobile: Experiences from Example

Vidya Setlur
Nokia Research Center
Palo Alto
vidya.setlur@nokia.com

Cynthia Kuo
Nokia Research Center
Palo Alto
cynthia.kuo@nokia.com

Peter Mikelsons
Nokia Research Center
Palo Alto
peter.mikelsons@nokia.com

ABSTRACT

Creating user friendly map interfaces for the mobile platform presents several challenges that are uniquely different from those of their desktop counterparts. High resolution, photo realistic maps can now be displayed on mobile phones. While these graphics are visually pleasing, they do impact the user's cognitive load. Further, small displays and limited interaction capabilities often make mobile map-based systems difficult to design and frustrating to use. In this paper, we discuss lessons learnt from designing and implementing mobile map interfaces through two examples: tourist maps and traffic maps. In particular, we discuss the rendering, user interaction, and system adaptations required for these mobile map interfaces.

Categories and Subject Descriptors

H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information SystemsMaps; H.5.2 [**Information Interfaces and Presentation**]: User Interfaces

General Terms

Design, Human Factors

Keywords

maps, mobile, design, interaction, optimization

1. INTRODUCTION

Mobile devices are the platform for a new generation of map-based services. Map-based visualizations are quite prevalent and commercially successful, particularly navigation systems and tourist guides. However, designers of mobile visualization systems face a range of difficulties related to limited screen size, interaction mechanisms, processing power, and memory resources.

The usability of mobile maps largely depends on the *rendering* of the information on the map [11]. In other words, a good map interface should minimize the amount of visual clutter on a small screen, yet assist users in finding the information they need. When the contrast between the relevant information and the other information is low, the search time is long and the display is cluttered.

Mobile devices offer interaction possibilities that desktop computers do not. For example, a mobile device with GPS technology (and other contextual information) can be used to deliver real-time map content that is relevant to users' personal and situational contexts. These mobile maps need to support real-time *interaction* that is intuitive and responsive. Common techniques for map interaction, such as zooming and panning, facilitate relevant access to content.

Finally, cellular network connections tend to be weaker and less stable than their fixed-line counterparts, leading to longer network latency and user wait time. In order to create a decent mobile user experience for map interfaces, *system optimizations* need to be considered. Shortening download times for map data and increasing the responsiveness of the user interface are essential.

Contribution. This paper discusses lessons learnt from designing and implementing mobile map interfaces through two examples: traffic maps and tourist maps. In particular, we discuss the rendering, user interaction, and system adaptations required for these mobile map interfaces.

COM.Geo 2010 June 21–23, 2010, Washington, DC, USA

2. RELATED WORK

Traditional cartographic techniques have inspired map rendering optimizations that are suitable for mobile consumption. LineDrive is a system for automatically designing and rendering route maps [6]. Kray *et al.* describe a method of presenting route instructions on a mobile device; the instructions depend on various situational factors, such as limited resources and varying quality of positional information [10]. Cheverst *et al.* developed a tourist guide system that blends navigation and information together to provide a user with a context aware device for vacations [8]. The system provides different levels of interaction depending on what the user wants, from a planned tourist itinerary to information about locations and places of interests. Informational map services, such as Google Maps [2] and Yahoo! Maps [5], attempt to address some of these challenges while providing routing and navigation; showing points of interest and optional informational overlays; and supporting interactions such as search and zoom.

Special strategies have been developed to help users navigate to off-screen content and develop awareness of spatial layout. Rotating Compass, an interaction technique

Figure 1: Retargeting maps for better readability. Left: Map of San Francisco rendered without any retargeting and stylization. Center: Map of San Francisco with retargeting and tourist map stylization applied. Right: Map of San Francisco with traffic stylization applied.

for pedestrian navigation on a mobile phone, indicates the correct walking direction to the pedestrian [15]. Rohs and Essl investigate different information navigation methods for handheld displays using a range of sensor technologies for spatial tracking [14]. Touch & Interact extends the phone output to a public display allowing both screens to share the display space for a tourist application [9].

3. MOBILE MAP APPLICATIONS

We will discuss mobile map adaptations in the context of two different projects, a tourist map and a traffic map. Both sets of maps were rendered using GeoServer, an open source software server for geospatial data [1]. The underlying map data were supplied by NAVTEQ; the data were modified to enable the rendering styles we desired.

3.1 Tourist Map

We developed an Objective-C-based mobile tourist map application to highlight points of interest (POIs) in a city. The map was rendered with cartoon-style exaggerations. More important POIs were displayed more prominently than less important POIs. Also, using a web service routing API [13], we found the routes from each POI to every other POI. Secondary roads that did not connect POIs were dropped from the map.

3.2 Traffic Map

We developed a Java-based application to view vehicular traffic on the roadway [4]. The viewer was part of a project to collect traffic probe data from drivers using GPS-enabled cell phones [3]. The application collected location and speed data from users' phones in a privacy-preserving manner; in return, it displayed real-time traffic information. The map colors were muted to convey traffic information quickly and accurately to users while driving. Irrelevant features were also removed.

4. MOBILE MAP ADAPTATIONS

The usability of mobile maps largely depends on the interaction with the map, the interaction with the device itself, and the rendering of the information on the map [11]. Along with the design of the map rendering and user interaction, technological challenges must be considered. Screen size, modality limitations (*i.e.* buttons, joypad, touch screen), and wireless connection speed have to be taken into account. In the following section, we provide an overview of three types of optimizations made to enhance usability in the tourist and traffic map applications we implemented.

4.1 Rendering

Mobile devices possess small screens, so effective visualization of information is extremely important. Visual clutter is highly influenced by the information density. Information can be occluded by information at the foreground, such as overlapping icons, text, and lines. When the contrast between the relevant information and the other information is low, the search time is long and the display is cluttered. To prevent clutter one can change the level of detail, use enhancement effects, aggregate objects, or remove irrelevant information.

In order to automate the process of rendering tourist and traffic maps for a mobile phone, we draw inspiration from a collection of perceptual cartographic techniques to reduce the scale and complexity of imagery while maintaining detail in important elements. Such techniques include:

- **Exaggeration:** Exaggeration consists of both size and line exaggeration rules. These rules are applied to *increase* the spatial detail and visibility of the map object. If the object is just a line stroke, such as routes in informational images, our system then applies line exaggeration, by increasing the line weight.
- **Elimination:** The process selectively removes regions inside objects that are too small to be presented in the retargeted map.
- **Typification:** Typification is the reduction of feature density and level of detail while maintaining the representative distribution pattern of the original feature group. Typification is a form of elimination constrained to apply to multiple similar map objects.
- **Outline Simplification:** Often the control points of the Bezier curves, representing ink lines at map object

boundaries become too close together resulting in noisy outline. We use a vertex reduction technique, which is a simple and fast O(n) algorithm. In vertex reduction, successive vertices that are clustered too closely are reduced to a single vertex.

Figure 1 shows a comparison between a map (left image) that is rendered without any rendering adaptation, and the other two maps with rendering adaptations applied for a tourist map and traffic map look-and-feel respectively. In the tourist map, unimportant roads, water bodies and patches of green are removed. Landmarks and their text labels are emphasized and exaggerated, and the outlines are simplified. In the traffic map, features that are irrelevant to traffic, such as POIs, are removed. Traffic lines are exaggerated with thick lines and bright colors.

4.2 Interaction

Mobile devices support a variety of interaction paradigms. The behavior for panning, zooming, and POI selection differ across devices.

- **Panning:** On PCs, clicking and dragging the mouse pans the map. Also, there is usually a control for panning on the side of the map. On devices without touch screens, users pan using a directional pad (D-pad) or track ball, similar to the pan controls. On touch screen devices, users pan by touching the screen and dragging their finger (or stylus), similar to a mouse. However, touch screen devices often show "momentum." When a user lifts her finger after panning, the map may continue to slide for a bit before stopping. The faster the pan, the more momentum the map has.
- **Zooming:** On PCs, the wheel on a mouse can be used to zoom in and out. On PCs and on all touch screen devices, double clicking/touching a spot on the map recenters the map and zooms in one level. On PCs and single-touch devices, zoom in and zoom out controls are available on the side of the map (see left image in Figure 2). On multi-touch devices, users zoom in by pinching and zoom out by stretching the map (see center and right images in Figure 2). On non-touch devices, zooming is supported using shortcut keys or menu buttons.
- **Point of Interest (POI) Selection:** On PCs, rolling over a point of interest, such as a search result or landmark, brings up information about the POI. The information bubble disappears when the mouse moves off of the POI. Clicking on a POI pops up a bubble with information about the POI. The information bubble may include more extensive information than the rollover bubble. Non-touch devices can behave like PCs, except the map moves relative to a target in the center of the screen. The target is equivalent to a mouse that moves around a stationary map. There is no concept of rollover for touch devices; tapping a POI will open its information bubble.

4.3 System

Mobile mapping systems need to be optimized for performance for several reasons:

- **Slower download speeds than most wired or Wi-Fi connections.** 3G network users in the U.S. report average download speeds of 901 Kbps to 1,940 Kbps[7]. Many areas are only covered by slower EDGE networks. In contrast, the average broadband speed in the U.S. is 3.9 Mbps[12].
- **Spotty data connectivity.** Many areas, even in densely populated metropolitan areas experience intermittent data coverage. Users traveling into an area with no coverage may discover they cannot download map information.
- **Limited battery life.** Applications using GPS and data connectivity consume battery power quickly.
- **Smaller screen size and lower resolution screens.**
- **Reduced processing power.**

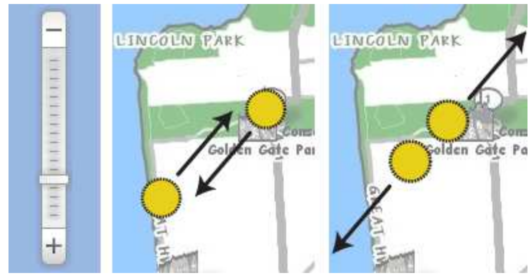

Figure 2: Common interactions for zooming in and out. Left: Control icons for zooming in and out on desktop map applications and devices with (single) touch screens. Middle: Pinch action for zooming out on a multi-touch screen. Right: Stretch action for zooming in on a multi-touch screen.

These factors affected a variety of system decisions in our maps. For example, some people favor vector-based maps that are rendered on the client. Vector maps can be rotated and "tilted" for a 3D view, and the rendering style of the map can be changed easily. Also, if the map data is stored on the client, the application is more robust to connectivity loss. However, downloading and displaying pre-rendered map image tiles reduces processing on the clients and speeds up the responsiveness of the map considerably. Performance considerations alone make pre-rendered image tiles a better choice for the user experience (for now).

Many desktop map sites use 256x256 pixel map tiles. Broadband connections are fast enough that the tiling is rarely noticed. On mobile devices, however, download speeds are slower, and missing tiles are noticeable. Moreover, a 256x256 tile comprises a large percentage of a screen that may only be 240x320 or 320x480 pixels in size. Thus, users may have to wait several seconds before they see a map. By reducing the tile size (to 128x128 pixels), we saw a considerable improvement, as parts of the screen would fill in while others were loading.

To maximize the responsiveness of the application, we also minimized the number of element layers. For example, the tourist map requires two layers: the base map, and the clickable POIs on top. The traffic application uses three layers: the base map; the traffic layer, a layer of transparent PNG tiles containing colored traffic lines; and clickable incident icons (see Figure 3.) Traffic information is placed in a separate layer because tile content changes frequently. Unfortunately, traffic information often covers important street names. When we pulled out the street names into an addi-

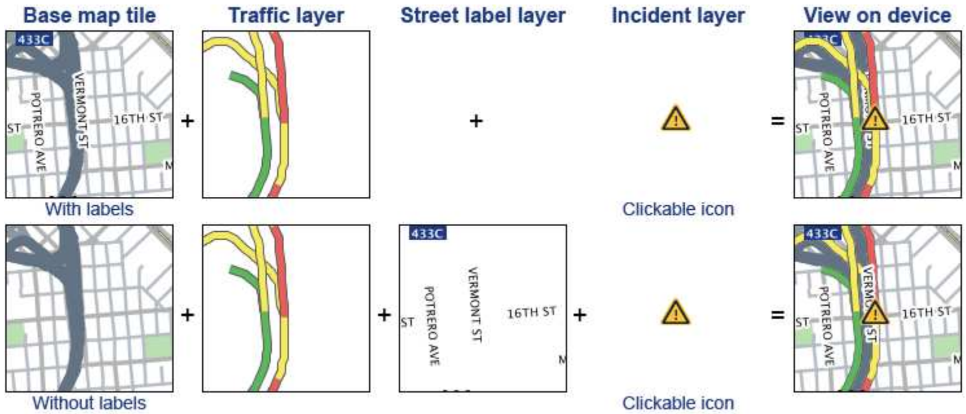

Figure 3: Map elements are separated into different layers for the traffic map application. Separating the street labels increased text readability (as shown in the bottom row). However, minimizing the number of layers (shown in the top row) improved the responsiveness of the mobile client, reduced clutter, and emphasized the traffic.

tional layer, application responsiveness decreased noticeably. Ultimately, we kept the street names in the base layer.

Finally, we cached base map tiles on the client. The tile cache improved performance significantly for areas that the user had already visited.

5. CONCLUSION

Mobile devices bring new requirements to map design. GPS location technology and different interaction mechanisms, such as multi-touch screens, support more context aware and intuitive map applications. However, device limitations, such as small screens, limited network connectivity, or reduced processing power, must also be considered in developing the user experience. This paper summarizes the rendering, user interaction, and system adaptations that were required for the tourist and traffic maps that we implemented.

6. REFERENCES

[1] GeoServer. `http://geoserver.org`.

[2] Google Maps. `http://maps.google.com`.

[3] The Mobile Millennium project. `http://traffic.berkeley.edu/`.

[4] Mobile Millennium Traffic Pilot. `http://traffic.nokiaresearch.com`.

[5] Yahoo! Maps. `http://maps.yahoo.com`.

[6] M. Agrawala and C. Stolte. Rendering effective route maps: improving usability through generalization. In *SIGGRAPH '01: Proceedings of the 28th Annual Conference on Computer Graphics and Interactive Techniques*, pages 241–249, New York, NY, USA, 2001. ACM.

[7] B. X. Chen. Verizon leads, AT&T runs last in Wired.com's 3G speed test. *Wired*, July 2009. `http://www.wired.com/gadgetlab/2009/07/3g-speed-test/`.

[8] K. Cheverst, N. Davies, K. Mitchell, A. Friday, and C. Efstratiou. Developing a context-aware electronic tourist guide: some issues and experiences. In *CHI '00: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 17–24, New York, NY, USA, 2000. ACM.

[9] R. Hardy and E. Rukzio. Touch & interact: touch-based interaction of mobile phones with displays. In *MobileHCI '08: Proceedings of the 10th International Conference on Human Computer Interaction with Mobile Devices and Services*, pages 245–254, New York, NY, USA, 2008. ACM.

[10] C. Kray, C. Elting, K. Laakso, and V. Coors. Presenting route instructions on mobile devices. In *IUI '03: Proceedings of the 8th International Conference on Intelligent User Interfaces*, pages 117–124, New York, NY, USA, 2003. ACM.

[11] R. Looije, G. M. te Brake, and M. A. Neerincx. Usability engineering for mobile maps. In *Mobility '07: Proceedings of the 4th International Conference on Mobile Technology, Applications, and Systems and the 1st International Symposium on Computer Human Interaction in Mobile Technology*, pages 532–539, New York, NY, USA, 2007. ACM.

[12] O. Malik. Akamai data: Internet, broadband still going & growing. *GigaOm*, March 2009. `http://gigaom.com/2009/03/27/akamai-data-internet-broadband-still-going-growing/`.

[13] NAVTEQ Network for Developers. MapTP AJAX API. `http://www.nn4d.com/site/global/build/manuals/ajaxapiintroduction.jsp`.

[14] M. Rohs and G. Essl. Sensing-based interaction for information navigation on handheld displays. In *MobileHCI '07: Proceedings of the 9th International Conference on Human Computer Interaction with Mobile Devices and Services*, pages 387–394, New York, NY, USA, 2007. ACM.

[15] E. Rukzio, M. Müller, and R. Hardy. Design, implementation and evaluation of a novel public display for pedestrian navigation: the rotating compass. In *CHI '09: Proceedings of the 27th International Conference on Human Factors in Computing Systems*, pages 113–122, New York, NY, USA, 2009. ACM.