Navigating Dynamically-Generated High Quality Maps on Tilt-Sensing Mobile Devices

Sven Kratz and Michael Rohs
Deutsche Telekom Laboratories, TU Berlin
sven.kratz,michael.rohs@telekom.de

Abstract: On mobile devices, navigating in high-resolution and high-density 2D information spaces, such as geographic maps, is a common and important task. In order to support this task, we expand on work done in the areas of tilt-based browsing on mobile devices and speed-dependent automatic zooming in the traditional desktop environment to create an efficient interface for browsing high-volume map data at a wide range of scales. We also discuss infrastructure aspects, such as streaming 2D content to the device and efficiently rendering it on the display, using standards such as Scalable Vector Graphics (SVG).

1 Introduction

Geographic maps are an example of a high-resolution and high-density 2D information space that is essential to many mobile applications. Interaction techniques for navigating maps on small-display devices with limited input capabilities are thus important for the mobile user experience. Geographic information in general is complex in that it is typically not sufficient to scroll or pan through it in a single plane, but it is often necessary to view it at a wide range of scales. A user might be interested in street names in the vicinity of her current location, but potentially also in the geographical location of cities when on a train or of countries when on a flight. There are thus at least three dimensions that need to be controlled in a general map navigation task (scrolling along in the plane and zooming in scale). The map navigation space is therefore an instance of a multiscale information space [GBL04].

Current commercial map navigation interfaces are almost exclusively based on keypad and multiway button input. Pressing and holding the multiway button in a chosen direction starts rate controlled scrolling, often accelerated in some way. Since the input is binary, there is no fine-control over the rate of scrolling and the movement can feel too fast for new users or too slow for experienced users. Zooming in and out has to be mapped to two additional buttons, which makes the change between scrolling and zooming quite clumsy.

To allow for more fine-grained and direct control, tilt-based browsing has been proposed for mobile devices. Here, the amount of tilting controls the rate of scrolling through a list of items or maps [Rek96, HPSH00, CCS$^+$07]. However, some studies found that even though users generally seemed to prefer tilt-based browsing, it is not always faster than keypad input.

Since map navigation not only consists of scrolling, but also requires zooming to different scales, tilting alone is not sufficient. Rather than introducing an additional control for zooming, as proposed in [MYN08], an alternative strategy is to couple scrolling and zooming to keep the velocity of the items moving on the screen at a constant level. In these *speed-dependent automatic zooming (SDAZ)* interfaces, originally proposed for desktop interfaces by [IH00], the goal is to keep the perceptual scrolling speed constant by gradually zooming out as the user scrolls faster through the document. The coupling of zoom level to scroll speed reduces the degrees of freedom of the interface that the user has to control simultaneously. Users preferred automatic zooming to the traditional scroll bar, but the effectiveness of the technique depends on the kind of feedback that is given in the zoomed-out state. It works best when appropriate visual cues are available to help the navigation.

Dynamically generated maps pose further problems, which makes further research necessary. Dynamically generated maps do not have constrained boundaries like documents or images. In Google maps, for example, the user has the ability to scroll from Paris to Berlin continuously. We propose a new approach to SDAZ in tilt-based mobile interfaces, called *semi-automatic zooming (SAZ)*, which allows the user to navigate in multi-scale information spaces.

2 Related Work

Eslambolchilar and Murray-Smith [EMS04] use SDAZ in a tilt-based interface for mobile devices and base their approach on control theory to realize a physically intuitive interface. For a tilt-controlled document browser they show that users prefer this interface over one without augmented control.

Expanding on the work described above we focus on a map interface whose scale level can be freely chosen. There is no notion of a "100%" zoom level and no zoomed-out state. Rather, users should be able to scroll a city map at street level, as well as a country map showing just the major cities. We suggest that tilt-based scrolling and SDAZ are still useful in this case, although a few modifications must be made. Since there is no "100%" zoom level, slowing down or stopping movement will decrease scale to an arbitrary reference level, which can be freely chosen by the user. Our interface offers a "reset" button, which recalibrates the reference zoom level and, when kept pressed, smoothly zooms out and decreases this reference level. We call this approach *semi-automatic zooming (SAZ)*.

Moreover, we think that strictly keeping the perceived scrolling speed constant is not useful or necessary. Rather, we allow for a slight increase in scrolling speed before zooming starts. We therefore propose an S-curve rather than a linear relationship between scrolling speed and zoom rate. Adjusting the parameters that control the relation between scrolling and zooming has been found to be an essential aspect for optimizing user performance in SDAZ interfaces [CSW05]. This has to be re-evaluated for small-screen interfaces.

Cho et al. [CCS$^+$07] developed a tilt-based photo browsing application and found that "attractors" around the photos made it easier to settle on them. The scrolling movement was influenced towards the photo centers. In a map application this approach can more generally be applied to define points of interest on the map, which should decrease overshooting. Tactile and auditive feedback can further support guiding the user towards a target. Moving towards "attractors" essentially modifies the control-display ratio [BGBL04].

3 Delivery and Display of Map Data on Mobile Devices

High-quality map information presents a problem for mobile devices, as they require a very large amount of storage capacity[1]. Except for high-range models, this amount of data exceeds the storage capacity of most mobile devices on the market today. A further problem arises in keeping the map data up-to-date. As an obvious solution to the problem of map storage, we propose to stream only the map data relevant to the user's current position and at the selected scale to the user's device. This can, for example, be achieved by using Web Services[2].

Services such as ArcIMS[3] or OpenStreetmap[4] could provide a basis to mobile browsing of high-quality map data. We believe that SVG-T (Scalable Vector Graphics - Tiny, a subset of SVG [5]) is the specification language of choice for rendering vector-based graphics on mobile devices. SVG-T is widely supported and even hardware-accelerated on current mobile devices[6]. A significant technical challenge, however, is the conversion of vectorized geoinformation data to visually appealing SVG maps. Two straight-forward solutions are thinkable. Either the raw map data is converted on-the-fly by the mobile device, or a proxy generates the SVG data upon a request by a mobile device.

We generally prefer the latter solution, as processing raw map data for display on a mobile devices requires significant computational resources which may be more efficiently bundled in a powerful server, that may also use caching methods to substantially reduce the amount of conversion operations required. We are unaware of any service providing direct GIS to SVG-T conversion at this time. In order to enable interaction with the map, such as panning, zooming and the selection of objects, additional metadata beyond SVG-T is required. The development of such an infrastructure, based on open standards, would be an important building block of future mobile map services.

4 Tilt-Based Map Navigation with SDAZ on Mobile Devices

Research Goal. We intend to build a prototype version of the map browsing system discussed in the previous section. Using this system, we aim to show how tilt-based map

[1] http://www.tomtom.com/products/maps/select.php?D=57&Language=3&P=420
[2] http://www.w3.org/2002/ws/
[3] http://www.esri.com/sotware/arcgis/index.html
[4] http://www.openstreetmap.org
[5] http://www.w3.org/Graphics/SVG/
[6] For example, SVG-T is included as a standardized API in current releases of the Java Mobile Edition (JavaME) platform. http://jcp.org/en/jsr/detail?id=226

navigation in conjunction with speed-dependent automatic zooming on mobile devices increases the effectiveness of 2D browsing tasks over the standard button interface with manual zoom control available on many devices.

Configuring Interfaces using Automatic Zooming. An important factor of the performance of SDAZ interfaces are the parameters that define the mapping from scrolling speed to zoom level, the values of the minimum and the maximum zoom levels and the speeds at which zooming in and zooming out occur. We are especially interested whether the parameters used in [CSW05, IH00] to evaluate optimal zooming characteristics for SDAZ can still be applied to applications running on the small screens present on mobile devices. These parameters defined in the literature include *screen movement rate* (SMR), *document movement rate* (DMR), *maximum ascent rate*, *maximum descent rate* and *maximum fall rate*.

The SMR indicates the speed (i.e. cm/s) at which the the document is visually moving across the screen, whereas the DMR represents the rate at which the document is actually scrolling. The idea behind SDAZ is to keep SMR constant when scrolling documents at a high speed, enabling the user to perceive his current position in the document even at high DMRs. Consequently, SMR equals DMR when fully zoomed in, and DMR increases in proportion to the magnification factor, while at the same time SMR should remain constant. The rates for maximum ascent and descent refer to the speed at which zooming in or our occur. *Maximum fall rate* describes the rate at which a SDAZ interface zooms in when all user input has ceased. These rates must be carefully chosen, as, for example, very fast zooming can confuse the user whereas very low zoom rates may make operation of the interface sluggish.

To obtain the correct parameters for a given interface, measurements of the interface's screen size and of the distance of the user from the screen are needed. The formulae developed by the authors to calculate the optimal values for the parameters by taking into account characteristics of the human perceptual system. [CSW05] define SMR and DMR as:

$$SMR = \frac{AppSize}{OnScreentime} \qquad DMR = \frac{SMR}{(mag/100)} \tag{1}$$

where *AppSize* is the height of the application window (in cm) and *OnScreenTime* is the time a recognizable object (such as a text heading) takes to traverse the height of the screen and *mag* is the magnification factor (in percent).

According to (1), a smaller *AppSize*, as is the case for mobile devices, leads to a smaller SMR. We expect that the *OnScreenTime* depends on the amount of information on the screen and therefore on the screen size. The empirical results presented in [IH00] showed an average *OnScreenTime* of 677ms which resulted in a DMR of 71,2cm/s. These results are, however, based on the assumption that the user has to identify and read headlines from a document that is scrolling past. For map navigation, a smaller *OnScreenTime* may be observable. We have reason to believe, that when browsing a map to find a specific location, for instance, the user is able to more rapidly understand what he is seeing. The user may be able to rapidly orientate himself by employing his spatial memory (if he knows the map or certain parts of it already) and making use of semantic features that maps provide, such

Figure 1: A prototype of a Semi-Automatic Zooming interface for map navigation. The user navigates the map with tilt and SDAZ, but can also manually adjust the zoom level with a slider (right).

as large bodies of water, airports, motorways or other prominent geographical features. As previous evaluations of automatic zooming were performed with settings optimized for 19” displays, it may be interesting to evaluate if the formulae found in the literature are also applicable to automatic zooming interfaces running on mobile devices with small screens.

Semi-Automatic Zooming (SAZ). To our knowledge, only interfaces exclusively featuring automatic zooming or manual zooming have been compared in the past. We have observed that standard SDAZ interfaces assume a certain maximum zoom level. This is not necessary for an interface designed to navigate freely scalable map interfaces, where scrolling can be performed from street to country level and where neither level represents a maximum zoom setting. SAZ gives the user some control over the zooming system (see Figure 1), which we believe has multiple benefits. For instance, map-browsing interfaces may benefit from a “clutch” function, which allows the user to remain at a given zoom setting, for instance to remain zoomed out, in order to give the user time to fully understand the context of what he is seeing and to plan his next input. Conversely, it may also be desirable for the user to “reset” to a zoomed-in setting for detailed searching tasks on a confined area of the map. We intend to evaluate the anticipated benefits of SAZ in our prototype.

Attractors to Points of Interest. Attractors help the user to select he target he desires and help to prevent overshoot errors. We believe that attractors coupled to points of interest (POI) on the map may make navigation easier for users looking for specific targets.

Prototype System for Evaluation. For initial rapid prototyping and evaluation, we intend to implement a simulator for our tilt-based map interface, which runs on a PC using the Google Earth API [7]. This simulator will incorporate the input modalities and especially the screen size of modern mobile phones. Tilt data can be obtained by using a Shake-SK6[8] integrated sensor device. If our initial results look promising, we intend to implement an expanded prototype of our system on an iPhone, which comes with a built-in tilt sensor.

[7] http://earth.google.com/comapi/
[8] http://www.samh-engineering.com/

5 Conclusions

We present suggestions for the creation of an architecture for online access and navigation of map data for mobile devices based on Web Services and the SVG-T vector graphics standard. We have identified the need for an efficient user interface for map navigation on mobile devices and it is our goal to evaluate if a tilt-based automatic zooming interface is superior to normal button-based interfaces. Furthermore, we have concluded that, in contrast to previous SDAZ interfaces, a need exists for the user to manually control the zooming process at certain times, a mode of interaction we defined as Semi-Automatic Zooming. Finally, we aim to verify if previous findings used to configure important parameters of SDAZ interfaces are still valid on mobile devices with small screens. We have not yet experimentally verified the ideas we propose in this paper, but we intend to conduct exhaustive studies once we have implemented a more mature prototype.

In the future, we aim to explore if it is beneficial to augment our map browsing system with simple gesture input obtained from acceleration and gyroscopic data. The ability to define spatial input using 3D accelerometers seems to be a promising alternative to using the 0D buttons on the device's keypad for navigation. This applies not only to maps, but also to other multiscale information spaces.

References

[BGBL04] Renaud Blanch, Yves Guiard, and Michel Beaudouin-Lafon. Semantic Pointing: Improving Target Acquisition with Control-Display Ratio Adaptation. In *Proc. CHI '04*. ACM, 2004.

[CCS+07] Sung-Jung Cho, Changkyu Choi, Younghoon Sung, Kwanghyeon Lee, Yeun-Bae Kim, and Roderick Murray-Smith. Dynamics of Tilt-Based Browsing on Mobile Devices. In *Proc. CHI '07*. ACM, 2007.

[CSW05] Andy Cockburn, Joshua Savage, and Andrew Wallace. Tuning and Testing Scrolling Interfaces that Automatically Zoom. In *Proc. CHI '05*. ACM, 2005.

[EMS04] Parisa Eslambolchilar and Roderick Murray-Smith. Tilt-Based Automatic Zooming and Scaling in Mobile Devices – A State-Space Implementation. In *Proc. MobileHCI*, 2004.

[GBL04] Yves Guiard and Michel Beaudouin-Lafon. Target acquisition in multiscale electronic worlds. *Int. J. Hum.-Comput. Stud.*, 61(6):875–905, 2004.

[HPSH00] Ken Hinckley, Jeff Pierce, Mike Sinclair, and Eric Horvitz. Sensing techniques for mobile interaction. In *Proc. UIST '00*, pages 91–100. ACM Press, 2000.

[IH00] Takeo Igarashi and Ken Hinckley. Speed-Dependent Automatic Zooming for Browsing Large Documents. In *Proc. UIST '00*. ACM, 2000.

[MYN08] Jonathan Mooser, Suya You, and Ulrich Neumann. Large document, small screen: a camera driven scroll and zoom control for mobile devices. In *Proc. SI3D '08*. ACM, 2008.

[Rek96] Jun Rekimoto. Tilting Operations for Small Screen Interfaces. In *Proc. UIST '97*. ACM Press, 1996.