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Visualization Approaches for Mobile Devices

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Abstract. The paper surveys compact visualization techniques for desktop applications and advanced visualizations for mobile devices. The developer has to consider computational and size limitations of the mobile device while developing visualizations. The paper explores traditional visualization methods and their modifications for small screens. The usage of mobile interfaces is in the focus and is illustrated by examples.

Keywords. User interface, mobile device, mobile interaction, small screen, compact visualization

Introduction

Information visualization techniques are often an alternative when automatic data analysis is too complex for the user to control and understand the results. In decision making the user needs to rely on provided data. Visualizations present data highlighting important aspects and hiding irrelevant details. User interaction with analyzed data can make visual exploration faster and increase confidence in the findings.

In this paper, mobile technology is defined as always available and turned on wireless devices that are intended to be worn, carried, or accessed by the person during normal daily activities. This definition comprises handheld devices such as mobile phones that are working mostly in the background of the main user activities and are used for short specific tasks. The nature of interaction with such devices differs from the work with desktop applications which normally are used for longer-lasting tasks and usually are in the center of user's attention.

Extending visual exploration techniques for mobile devices will support user's decisions where and when they are needed. Mobile components became a requirement for contemporary systems. A mobile application runs on a mobile device and is used during normal daily activities.

The rapid development of mobile devices has significantly extended their technical limitations. According to Digital Trends report [1], resolution of smart phones reached 1920 x 1080 pixels in 2013. Although the screen resolution of mobile devices has been increasing, screen size is still much smaller than that of laptops and PC monitors [2].

Interaction with smart devices is also a challenge. Soft keys on touch screens take place. Thus, compact visualization techniques and intuitive interaction methods are needed. We further explore compact visualization techniques which maximally utilize small space.

The main challenge designing mobile interactions concerns device mobility. Desktop computers have a stable usage context that comprises among others lightening and loudness. In physical rooms recurring activities usually take place whereas mobile devices work in highly variable environments. Such variable environments have implications not only to colors and graphics that are differently perceived in light and dark environments. Environment change implies different usage scenarios.

Mobile technology is commonly used because of obvious advantages, such as convenience, availability, and ease of use. Mobile devices became a part of daily routine, provide constant connectivity, and support effective information management. They utilize embedded sensors unavailable in desktop computers: geographical positioning, proximity, accelerometers, pedometers, light and physiological sensors, etc. Sensors enable adaptation to geographical position allowing location-awareness and usage of specific proximity parameters enabling context-awareness.

This paper concerns compact visualization techniques of large information spaces for desktop applications. However, we aim to apply them for mobile devices (hereinafter mobile visualization). The study is based on literature research. The examples were selected to demonstrate the compact representations of large data spaces.

1. Compact Visualization Approaches

Visualization methods deal with information spaces that do not fit a screen. To explore large documents effectively, desktop applications usually provide views from different perspectives. The summary view provides a generalized context of information, for example document maps and thumbnails. It facilitates faster access to the required content. In the detailed, the content is readable. Considerable effort has been devoted to the study of different representations and navigation techniques, especially for large documents and 2D data spaces which are used in desktop systems. Visualization methods differ in a way how they summarize the information context and how the displayed detailed view is related to that context.

Traditional solutions for desktop and mobile devices comprise [3, 4]:

- restructuring of the information space,
- scrolling/panning and zooming techniques,
- overview&detail approaches,
- focus&context approaches,
- contextual cues or off-screen object visualization.

Restructuring the information space is a universal technique for both desktop and mobile applications. The basic approach consists in manually designing specific web pages for each target device. Automatically reformatting can be a possible solution, too. A typical approach is to transform multi-column layout into a single layout. However, after such transformation the navigation structure changes significantly and the orientation becomes more difficult. Another approach is to preserve original layout by compressing the whole space into a thumbnail. The layout is recognizable and reduced textual areas provide a readable summary, i.e. summary thumbnails [5]. The summary view is timely separated from the detailed view.

Traditional scrolling/panning and zooming techniques are used when information restructuring is not possible. The space is scrolled horizontally and vertically and also part of the space is panned out in any direction. The screen contains part of information space. Compact and unreadable summary view is available by zooming. Navigation requires cognitive effort because the user has to remember the off-screen information.

Overview&detail visualizations provide simultaneusly summary and detailed view in one screen. An example of overview&detail visualization is the context maps (Figure 1). This approach reduces cognitive workload by making visible space, which is not visible in the detailed view.

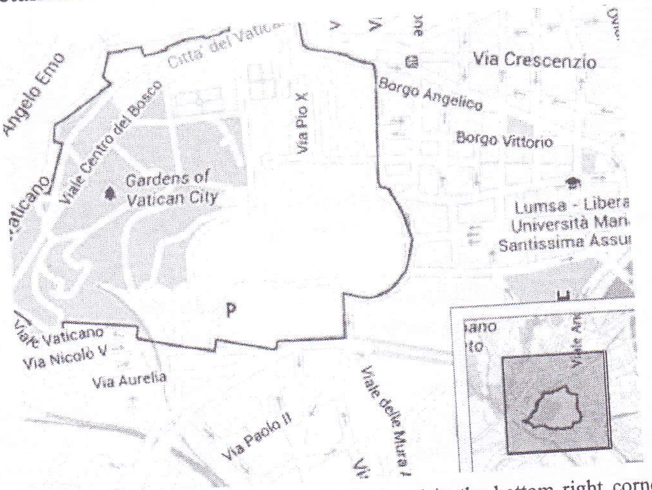

Figure 1. Context map: the compressed overview is displayed in the bottom right corner where the box highlights which part of the overview is displayed in the detailed view (image created using http://www.rome.info/map/)

The summary view typically overlaps a part of the detailed view space. This drawback can be solved by displaying the overview on demand. This option maximizes the detailed view space but makes impossible to see two views at the same time. It requires users to switch attention from one view to another and to remember the content of the off-screen view.

Overview&detail visualizations present the whole information space on a small screen. There are usability studies which present conflicting results. A study of the scatterplot navigation has not shown benefits of the overview [6] whereas investigation of map search tasks showed that overview increases user effectiveness [4]. The screen space assigned for a overview is insufficient for an easy interaction in the detailed view [3]. Some benefits were found in search tasks, when the user easily manipulates with an overview and the objects of interest are highlighted [7].

Focus&context approach [8], [9] is an alternative to overview&detail. It displays the information space at different levels of detail simultaneously without separating the different views. Techniques based on this focus&context approach use geometric distortions. Detailed part is undistorted whereas the surrounding context is reduced. Usually the whole space is available on the screen. An example of such approach is the fish eye view that integrates context and focus into a single view [10] (Figure 2 a).

Focus&context magnifies the local region of the information space. Location-aware applications utilize this approach by magnifying of object of interest while maintaining visibility of the contextual regions. Examples of mobile location-aware applications presents metro layouts in focus&context view. Traditional metro schema (Figure 2 b) is distorted in order to magnify passenger's route [11].

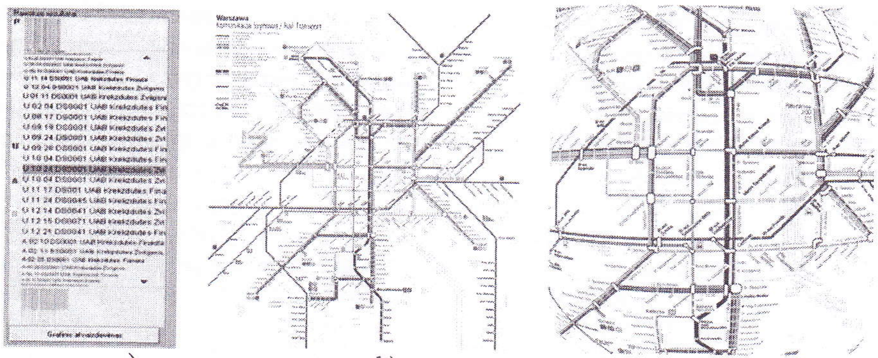

Figure 2. Fish eye views: a) menu in the desktop decision support system [10]; b) original metro map[1] c) focus&context map obtained using fisheye (adapted from [11])

Overview&detail and focus&context techniques facilitate the exploration of large information spaces. They introduce additional interaction. However, the cognitive costs make them unsuitable to explore undistorted content and perform spatial tasks in real time.

Off-screen object visualizations add abstract objects to the screen and provide awareness about off-screen objects located in their direction [9, 12, 13]. Abstract objects are compact graphical representations such as points, lines, arcs or circles which are placed along the borders of a window (**Figure 3**). They help to assess the distance from the visible space to the off-screen object of interest. This technique does not clutter the display and supports location-awareness.

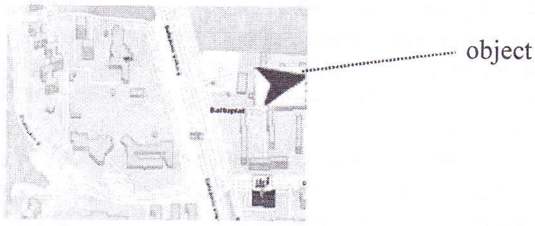

Figure 3. Scaled arrow show direction and distance to the off-screen object (adapted from [14])

2. Advanced Visualizations for Mobile Interaction

In this section we explore the interfaces that utilize specific mobile device capabilities and help people do more with their mobile phones taking them less time and attention. The minimization of user's cognitive workload was also regarded in desktop interfaces. Cognitive workload is actual when the screen contains only a part of needed information and the user has to recall the missing part. For example, focus&context technique shows the whole information space in the compressed summary view. The part under attention is magnified. The screen space of mobile devices is even more limited. Therefore, the compact techniques are needed that help mobile users to access large amount of data.

[1] Metro maps from www.skyscrapercity.com/showthread.php?t=367975&page=24

Mobile devices allow to log user's behavior, for instance, to have the list of calls. Behavior ring is a compact visualization technique that enables the visual analysis of tracked timing data. Figure 4 demonstrates how behavior ring helps to identify phone calls pattern during the week. The length of the radius depicts the number of calls. We can see on the left figure that there are more calls on weekends than on weekdays. The right ring illustrates the daily behavior and allows noticing the increase of calls in the evening and the night.

Behavior rings utilize specific features of mobile devices:

- interoperability – subject's behavior is tracked using embedded sensors,
- integration – behavior tracking is integrated into existing activities and supports the desired behavior,
- engagement – enables user involvement by providing instant feedback in order to sustain desired performance.

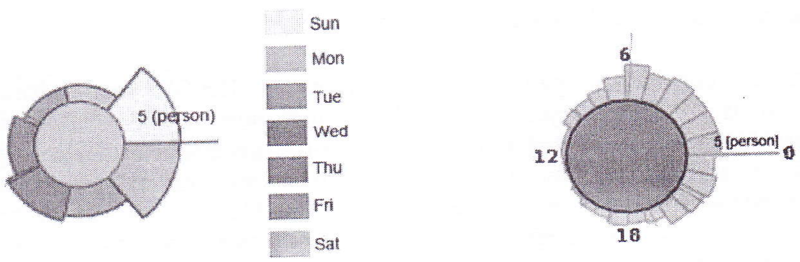

Figure 4. Behavior rings: the left ring shows the amount of the tracked activities. It reveals more tracked activities on weekends. The right chart depicts hourly ring – more activities on the night (adapted from [15])

2.1. Screen Clutter Reducing Technique

Visualizations of sensor data streams can become cluttered. Clutter-aware visualization techniques offer problem-solving by providing real-time qualitative solutions. An example of a clutter-aware adaptation is presented in [15]. Clutter is defined as the number of visualized units exceeding a preset threshold. Three kinds of the threshold in the clutter definition can be distinguished. First, the total area of circles (Figure 5 a). Second, a number of circles. Third, the number of overlapping circles.

The visualization starts with showing clusters on the screen. The cluster size reflects the number of data elements in the cluster. The process proceeds by assessment of screen coverage and cluster overlapping. If one parameter exceeds the user defined threshold (Figure 5 a), the visualization changes to the first level adaptation called scaling. Next, all clusters are proportionally reduced (Figure 5 b). In the case the smallest cluster is underscaled, the second level adaptation is applied, called shading (Figure 5 c). Second level adaptation sets the same size to all clusters. Each cluster is drawn with different intensity of color. The darkest clusters represent ones with highest number of points, while the white clusters represents ones with lowest number of points. If number of clusters is still greater than threshold or overlapping still holds, visualize switches to the highest level of adaptation, selection. Only active clusters are shown. Active clusters are defined as ones that have attracted new data points in the most recent time intervals.

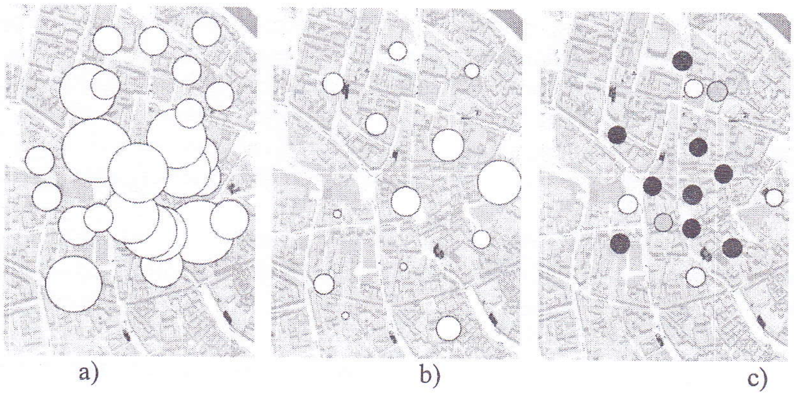

Figure 5. Clutter-aware adaptation: a) the screen is covered with overlapping clusters; b) clusters are reduced; c) shaded clusters (adapted from [15])

2.2. Visualizing Social-Spatial-Temporal Data

Mobile data can contain both spatial and social information. The GPS sensor identifies spatial locations of tracked subjects. Bluetooth proximity relations fix social relations among the subjects. Usually spatial information is shown on geographical maps, whereas social relations are shown as a social network graph. In the case these data are presented separately, the user has to switch. For example, the system MobiVis [16] demonstrates that these two views can be integrated. Here one compact view shows social relations and geographical positions. This view helps finding the hidden correlations between the social and spatial information.

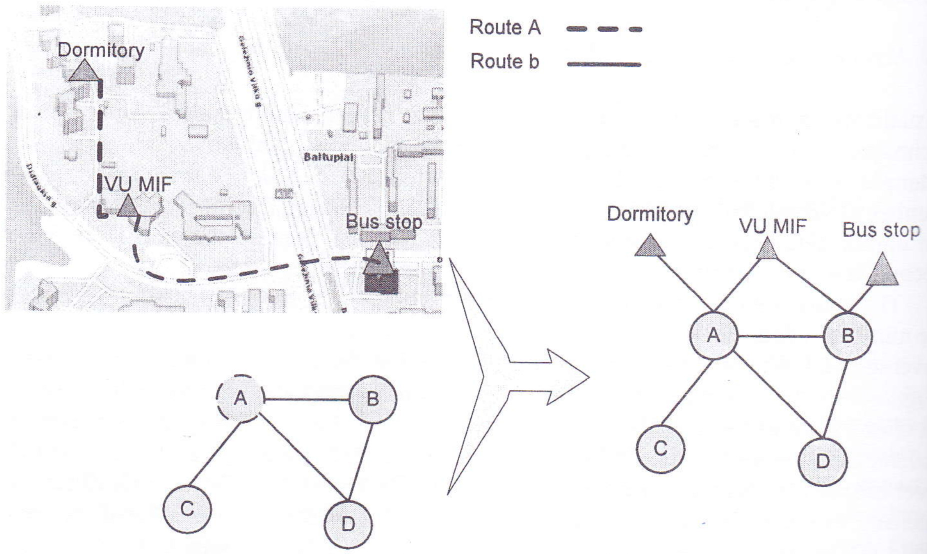

Figure 6. Top view shows the spatial view the social network. The bottom view shows social relations. The view on the shows the integrated heterogenous network (adapted from [7])

3. Conclusions

The paper present an overview of the compact desktop visualizations and advanced mobile visualization techniques. Overview&detail and focus&context desktop visualizations can be compact and accommodate large information spaces. Focus&context have more applications in mobile devices. The location-aware applications use this approach in mobile applications. Overview&detail needs more space for two visualization modes. Overview&detail requires switching between views. This increases the use's mental effort. In the small screen overview overlapps detailed view that makes interactions less convenient than focus&context. Interaction in focus&context can be more effective with the stylus than fingers.

The advanced mobile visualizations better fit the peculiarities of mobile devices. The examined mobile visualizations utilize embedded sensors, location and call data. This supports data analysis in real-time.

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