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Towards Visual Data Exploration at Wall-Sized Displays by Combining Physical Navigation with Spatially-Aware Devices

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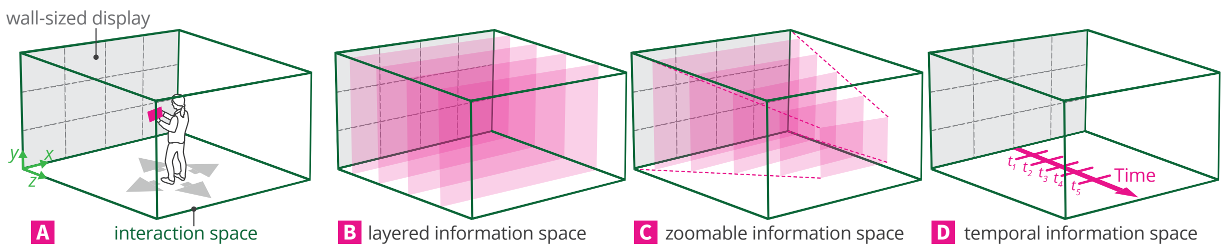

Figure 1: **Using the space in front of a wall-sized display:** (a) Volume with the Z-axis that is perpendicular to the reference surface; (b-d) Layered, zoomable, and temporal information spaces placed in front of the display.

Abstract

We present our work on the use of spatially-aware mobile devices in front of wall-sized displays for data exploration and navigation. The basic idea behind this work is to navigate data sets by walking and moving a mobile device within an interaction space. We describe mappings of different types of information spaces and report on results of a preliminary study regarding layered information spaces. We illustrate the potential of such a new data analysis interface by describing a prototype application that both visualizes traffic data and allows for performing comparison tasks.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction techniques; Human-centered computing—Visualization

1 Introduction and Background

Wall-sized displays provide great potential for visual data analysis and information visualization (InfoVis). Due to their display size, they enable interfaces that can show more data, more visualizations, and support collaboration. Previous work showed that users naturally move in front of such displays in form of physical navigation [1], which can offer improved user performance. Another interesting research direction is the use spatially-aware mobile devices for data analysis [2, 3, 7], showing that device interaction and movement can support orientation and navigation of complex information spaces.

The goal of our work is to investigate the use of spatially-aware mobile devices in front of wall-sized displays for data analysis. This is mainly inspired by Spindler et al.'s research on *tangible views* [5, 7]: They used the physical movement of spatially-aware displays above an horizontal context display, i.e, a tabletop or interactive surface, for the exploration of different information spaces. The question is, what are the consequences and implications of bringing such concepts from setups with horizontal displays to spaces with large vertical displays? Recently, Kister et al. [4] showed how mobile devices can be used to explore graph visualizations on large displays. However, we think that this type of data analysis interface is still underexplored and little is known about how to design them in a way that supports data analysts. We therefore want to improve our understanding on the combination of *physical navigation* with the use of *spatially-aware mobile devices* in front of wall-sized displays.

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2 Use the Space in Front of Wall-Sized Displays

The basic idea behind our work is to explore and navigate a data set by walking and moving a mobile device within an *interaction space*. A large and stationary display provides the contextual and central visualization, and mobile devices display portions or different visual representations of the data according to their location (i.e., position and orientation) in the exploration space (see Fig. 1). We extend the definition by Spindler et al. [5, 7] and describe such interaction spaces for vertical displays as a *3D real-world volume in front of a vertical reference surface with the Z-axis that is perpendicular to its surface.* Fig. 1b-d illustrates variations of different types of information spaces for vertical displays (adapted from Spindler et al. [5]): layered, zoomable, and temporal information spaces.

From Horizontal to Vertical Displays When comparing setups that use horizontal [5, 7] or vertical reference displays, the following differences emerge and need to be carefully considered for the design of InfoVis applications. First, in many cases vertical displays are ***larger*** than horizontal displays. While this allows to display either more or larger visualizations, it might also increase the interface complexity or encourage sensory overload. The large size also leads to a ***larger interaction space*** available in front of the display. It fosters physical navigation, which can have positive effects on orientation and task completion times [1]. However, depending on the duration and activity of working sessions, it might also involve higher physical demands. Due to the viewing angle, vertical displays also allow for a more flexible movement as well as ***various distances*** from which users can look at it. At horizontal displays, however, users typically walk rarely but stand directly at the device.

3 Local Interaction Spaces

The interaction space mentioned above uses the complete space in front of the large display. Alternatively to this global space, information spaces can also be placed locally (see Fig. 2), especially for layered and temporal information spaces. Instead of walking through the space, the hand-held device is moved locally, most likely along an axis between its original location and the user's head. While arm movement is less physically demanding, it allows to navigate, for example, a stack of layers from various positions in front of the large display. It would also be possible to use the global and local space independently to navigate individual data dimensions.

Preliminary Study As a first step towards the use of a global or a local interaction space, we started investigating the selection of

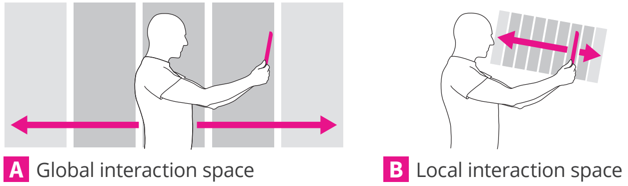

Figure 2: Difference between information layers placed (a) **globally** and (b) **locally**.

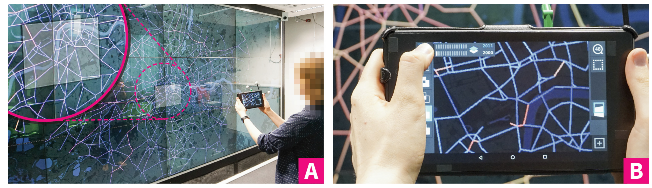

Figure 3: **Prototype application:** (a) Pointing to select a map section; (b) Selecting a year (clutching).

target layers of a layered information space (Fig. 1b) by conducting a preliminary study. In case of the global space, the space is divided into discrete parallel layers that are standing in front of the wall-sized display. Layer selection can be achieved by walking forwards or backwards in relation to the large display (Fig. 2a). For the local space, the stack of layers is placed at the mobile device's 3D position (Fig. 2b). To navigate through the stack and select a specific layer, the user touches and holds a clutch-button on the mobile device, then moves the device, and finally releases the button.

For the preliminary study, 20 students (8 female, 12 male) from the local university volunteered. The average age was 26 years (M= 25.54, SD= 2.72). The study took place in a controlled lab environment. We used ASUS Nexus 7 (7" display, 330 g) as a mobile device. To track the location of the device, we used a motion capture system mounted to the ceiling. This system covered an area of approximately 5.3×3.5 m in front of the large display, which had a size of 5×2 m. Based on a previous study on multi-layer interaction [6], we ask participants to perform five sequences of 13 layer selections: 1×25 cm, 2×20 cm, 2×15 cm, 2×10 cm, 3×5 cm, and 3×2 cm. Since each participant performed tasks for both a global and a local space, this resulted in sessions of approx. 20 min and a maximum of 130 selections per person.

As first results (without full statistical analysis), we found that it was easier to complete the sequences in a global space, as people failed more ofter in reaching thin layers in local spaces. We also observed less overshooting for the global space. However, it seems that if thin layers could be selected, completion times are lower for local spaces. Interestingly, the physical demand reported by participants was higher for local spaces. While one reason might be the more frequent overshooting, we think this could also show that for shorter working sessions walking is less problematic than one would imagine. Finally, we found that it might be beneficial to consider a transition between the concept of global and local spaces, since many participants seemed to try to compensate rough body movements (walking) with subtle arm movements.

4 Example Use Case: Traffic Visualization

In addition to a study application, we started implementing a prototype application for the visualization of traffic data. Currently, we use real-world traffic data of Greater London published by the Department for Transport (UK Government). This data represents a temporal information space, since the data set consists of street-level traffic count for different years (2000–2015). The python-based application running on the wall-sized display presents a full-screen map visualization, which shows a color-coded road network for the year 2000 (see Fig. 3a). For the technical setup we reuse the components from the experiment described above.

Interaction Concept Our goals is to support comparison of traffic data between years by selecting a map section and then exploring traffic development within this section over years. For that, we use a focus & context approach: the wall-sized display provides the context and shows data on one year (Y_1); and a mobile device is used to select another year (Y_2), specify a map section, and to visualize the result of comparing traffic data between Y_1 and Y_2 within this section. To specify a map section (see the rectangular highlight, Fig. 3a), the mobile device is pointed towards the display. Through pointing, one or multiple users can freely select any region of the map. Next, we apply the concept of a local interaction space for the selection of the year Y_2. This can be achieved by touching and holding a year-button (clutching) on the mobile device (see Fig. 3b) and then moving the device back-and-forth. The application then calculates the differences between the two years (Y_1 and Y_2) and finally shows the result of this comparison on the mobile device. The interface also provides further functionality (Fig. 3b). For instance, the size of map sections can be manipulated in the same way as the year selection by using another clutch-button. Besides choosing set operations (e.g., difference, intersection, union), a user can switch between the pointing methods projective and orthogonal. The pointing can also be deactivated completely. This, on the one hand, enables users to freeze a selected map section and, for example, continue an exploration within this area without facing the large display. On the other hand, the selection of a map section can alternatively be manipulated by performing drag or pinch-to-zoom gestures on the mobile device. Finally, the prototype supports multiple mobile devices, which enables collaborative data analysis.

5 Conclusion

In this work, we present our ongoing investigation on the navigation of data sets by walking and moving a mobile device in front of wall-sized displays. Besides first insights on the navigation of layered information spaces, we presented a first prototype implementation, which visualizes traffic data and allows to perform visual comparison tasks. An interesting open question regarding layered interaction spaces is the layer thickness. Particularly when users need to navigate with a specific layer by moving along the large display (in parallel). As the display size benefits use cases that involve multiple data analysts, we also want to further investigate collaboration and support visual comparison tasks carried out by multiple users. We hope that our work illustrates the potential of such new types of data analysis interfaces and that it can serve as a basis for further investigations and discussions.

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