Figure 1: Exploring data visualizations on LHRD from various positions: two users interact from a distance (a), approaching the LHRD for direct touch interaction (b), moving an exploration tool (magic lens) across a map visualization (c), and a rectangular pointing cursor for one of the devices (d).

Combining Interactive Large Displays and Smartphones to Enable Data Analysis from Varying Distances

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Abstract

Large high-resolution displays (LHRD) can benefit information visualization due to their size and resolution. As users often move back and forth in front of the display, we need to investigate what tasks should be supported from varying distances. In this work, we combine touch interaction on a LHRD with casual, 'eyes-free' device interaction using smartphones from a distance. We describe early insights and discuss important questions based on experiences with our prototype implementation.

Introduction & Background

Large high-resolution displays can excel in information visualization (InfoVis) [2, 11]: More pixels allow to visualize more data, more views. LHRD also have particular potential for visualization tools that take advantage of natural user interfaces (NUI) and support collaborative data analysis [5]. Previous work on NUI for InfoVis [9] mainly focused on input modalities, such as direct touch interaction [10], mid-air gestures [1], body movements [1, 6], interactions using mobile devices [4, 7], or natural language [12]. However, each modality has both advantages and disadvantages. For example, touching data items benefits from a directness and today's familiarity, but the size of LHRD can cause problems of reachability. Mid-air gestures enable remote interaction but particularly require recall. Body movements can interfere with natural movements (cf. physical navigation [2]).

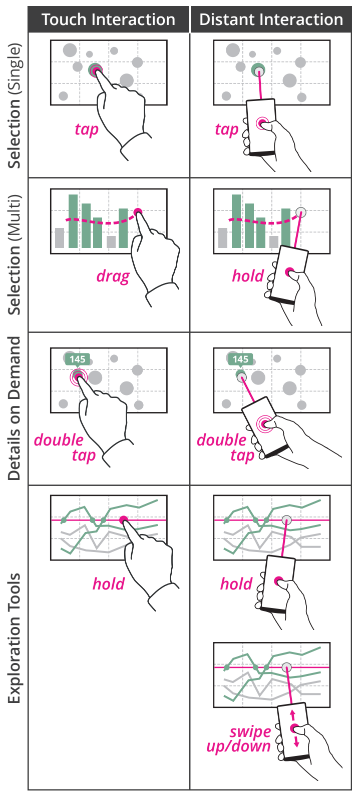

Figure 2: Context-sensitive *interaction mapping* for selecting data items, accessing details on demand, and activating or deactivating exploration tools.

In context of visualization systems running on LHRD, we believe that users will benefit from the opportunity to interact from various positions or distances. Due the success of interactive surfaces, people's first action when seeing a 'bright shiny display' is to touch it. At the same time, people also naturally step back a few steps in order to get an overall impression (overview) and to feel more comfortable [4, 7]. However, it seams clear that being forced to approach the display for every interaction can be frustrating. In this paper, we therefore describe an interaction concept supporting data explorations on LHRD from various distances. We combine direct touch interaction on the LHRD with casual, 'eyes-free' device interaction using smartphones. Besides describing the basic concept, we discuss early insights and point out important questions based on experiences with our prototype implementation for multiple coordinated views (Figure 1).

Integrate Distant Visualization Control

Future large displays are likely to be touch-enabled and visualization applications will certainly rely on this input modality. To address distant interactions, we propose to integrate mobile devices as personal *distant visualization controls* into such setups. Those are easily available, affordable, and already widely used in diverse situations. The basic idea is to use the smartphone in a way similar to a laser pointer. By pointing a device towards the LHRD and then touching its screen, people can easily interact with interface components or elements from any position in front of the display. To achieve this, our prototype tracks the device locations (6DOF) and implements an input injection strategy: All touch events from the mobile device are directly converted to touch input events on the LHRD at the pointed position (pointing cursor).

Interaction Mapping

Main goal of the interaction mapping is to provide consistency between the two input types: Once a user knows how to interact with direct touch, the same actions can be performed from a distance by using a smartphone. We also aim to make use of basic touch interactions, allowing casual and 'eyes-free' operation of the mobile device, i.e., users can perform touch input anywhere on the smartphone without looking down at the screen. Figure 2 gives an overview of the context-sensitive interaction mapping. To select single data items, users can directly tap them or point towards them and perform the tap on the device, respectively. Multiple data items can be selected by encircling or crossing them. While users simply perform a drag on the LHRD, the equivalent distant interaction comprises a hold gesture on the smartphone's screen and reposition of the pointing cursor. Items can be deselected individually using tap or globally by performing a double-tap on a visualization's background.

Our prototype also provides exploration tools, such as interactive guides (rulers) and magic lenses. To activate a tool, users touch and hold at the background of a visualization or point towards the background and perform the hold on the smartphone, respectively. Tools can be moved across a visualization using drag and drop. Again, distant drag and drop implies to point at the tool, perform a hold gesture, and then move the pointing cursor. Tools can be deactivated (closed) by a hold gesture on them. Mobile devices can further allow to use additional shortcuts. For example, an alternative for tool activation is to point towards the visualization's background and then perform a swipe-up gesture on the smartphone. A tool can also be deactivated by pointing at it and swiping downwards on the mobile device.

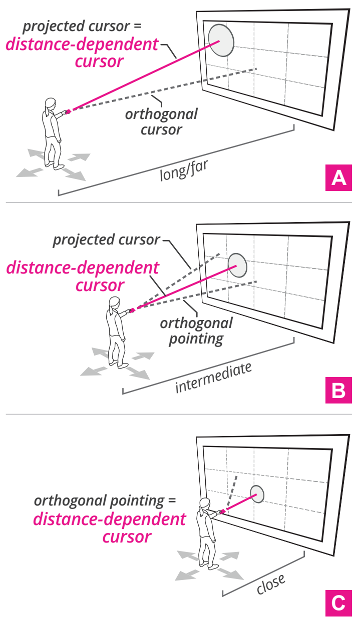

Figure 3: Functionality of the *distance-dependent pointing cursor* at different positions: overview distance (a), intermediate distance (b), close-proximity (c).

Distance-dependent Pointing Cursor
Reliable pointing is crucial for the proposed interaction style. A typical challenge in pointing is to balance easy reachability of all display regions while at the same time assure stability and precision. To address this, we additionally make use of the distance between the LHRD and the mobile device. In our prototype we implemented a "*distance-dependent pointing cursor* that provides a smooth transition [or interpolation] between projective and orthogonal pointing" [8]. The basic idea of this approach is to allow fast and rough interaction at overview distances as well as precise and accurate interaction at close-proximity (see Figure 3).

Among others, our design also considers concepts for linked brushing, details on demand, tool configuration, and visually different pointing cursors supporting multiple users.

Discussion
During the development and initial tests, we identified several aspects and questions that need to be considered for the design of information visualization applications using LHRD and the interaction space in front of them.

Natural Movement as Explicit User Input
Natural user movements (and proxemic interactions) have been used diversely in previous work [1, 6]. One of the most interesting questions for application designers is 'How to reasonably map user movements to system reactions?' Can those only be used for 'local' changes or actions with limited visual footprints [10]? If a use case intensively involves physical navigation [2], shall movements be used as explicit user input at all? Thus, there still is a need to further improve our understanding of how users behave in front of large displays while exploring visualizations.

Use of Mobile Device
Although many people use mobile devices very frequently, it is yet unclear whether their use for data exploration with LHRD is beneficial or rewarding. It can certainly be a limitation to hold them and not have the hands free. However, the proposed interaction style attempts to allow a casual or loose use, that is users do not need to focus or even look ('eyes-free') at the mobile device. This is different from approaches like GraSp [7] and it is yet unclear if and when each style is to be preferred. We also noticed that people use their dominant hand for both holding the device and touching the LHRD, which requires them to switch the device to the non-dominant hand. Because in our design modalities are chosen based on distance, they are typically not used simultaneously. Depending on how problematic this feels to users, other remote input modalities such as gaze plus mid-air gestures could address this issue.

Distance-dependent Task Support
The interaction design mentioned above focuses on the best possible flexibility: Users are free to choose when to touch the LHRD directly and when to use the mobile device for distant interaction. We aim to identify and better understand demands regarding distant interactions for data analysis. What tasks, type of actions, or goals need to be supported from a distance? Is there a relation between distance and the visual footprint of interactions [10]? Furthermore, what are important factors of influence, such as size and number of views? Large visualizations can be controlled from a distance more easily, while a large number of *multiple coordinated views* might encourage interaction in close-proximity due to the size of each visualization.

Collaboration
An additional advantage of distant interaction is that users can stay together during interaction, which has been shown to be beneficial for collaboration [3]. At the same time, distant interaction may cause conflicts between users: While close touch interaction restricts the user's effects to their smaller field of view, distant interaction enables a wider in-

teraction scope. As a result, this may result in conflicts, e.g., interaction on same items (elements, views, etc.) due to reduced awareness of the other user's focus.

Conclusion

This work presents parts of our interaction mapping to support data analysis both on and in front of LHRD, using mobile devices as an extension of the arm's reach. We discuss open questions and important aspects regarding the use of distance for interaction, which are part of our ongoing investigations and current user study focusing on user behavior at LHRD (movement, interaction modality, etc.).

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