Supporting Graph Exploration Tasks on Display Walls Using Spatially-Aware Mobile Devices

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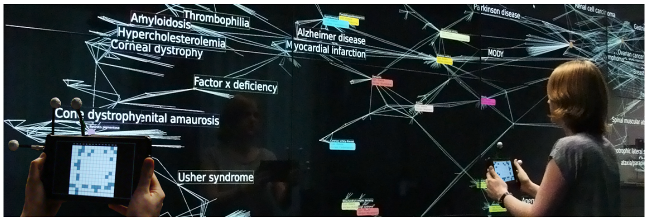

Figure 1: Combining mobile devices with wall-sized graph visualizations supports individual selections, views and lenses.

Abstract

Graphs are important data structures for relational data. Visual analysis of large data sets can be difficult on common display sizes. In our work, we investigate the promising combination of wall-sized high-resolution displays with spatially tracked mobile devices for graph exploration. We contribute concepts that use the mobile device to support selection, present additional information, or apply lens functions. This creates personalized mobile views in front of the large context visualization, enables seamless transitions between focus and context, and therefore provides a rich toolbox for a variety of tasks related to graph analysis.

Index Terms: H.5.2 [Information Interfaces and Presentation (e.g., HCI)]: User Interfaces—Input devices and strategies

1 Introduction

The node-link representation of a graph is easy to grasp and human readable but loses its clarity with an increasing amount of complexity because the visualization gets cluttered. One possible solution to address this problem is the use of larger screens which provide enough physical space to display large graph data. However, beside existing visualization challenges, this also results in challenges concerning interaction, as common techniques for desktop visualization and its interactions are often non-transferable. We argue that this requires novel approaches that provide a focused, personal view onto the wall-sized data representation and support selecting a specific region of interest, investigating its details, and filtering the information space while the user moves in space to explore the entire graph structure.

Previous research has shown that physical movement in front of the display supports understanding and analysis of information visualization [4]. However, when multiple people work and move in front of a wall-sized display, individual views can help prevent conflicts between users. The use of additional displays and their spatial movement for data exploration has been shown to have great potential above horizontal context displays [6]. First works in multi-display setups show that the interplay between mobile device and large displays can enable data transfer and control of elements on remote screens within multi-display environments [1].

In this work, we present our investigation into graph analysis as a foundation for the promising combination of lightweight, tablet-sized mobile devices and large display walls applied to data exploration. Furthermore, we contribute our specific approach for mobile use in front of display walls and its implementation supporting essential tasks in graph exploration.

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2 Concept for Graph Exploration

The basis of our approach is to take advantage of the space on and in front of wall-sized displays to support large data exploration. Hence, for our follwing concepts, the wall-sized display presents the main visualization and overview of the information space. On the other hand, the personal display is used to show individual detail views, focus points, and additional information. The mobile device's position and movement (and thereby an estimate of the user's position) is tracked in the space in front of the wall-sized display using an optical tracking system, so that individual interactions with the mobile device can be linked to specific objects on the display wall. In the following, we discuss a selection of techniques for this promising scenario starting with selection both near and far from the display wall as well as subsequent mobile views and lenses.

2.1 Selection

Selection is one of the most basic and essential tasks for data exploration [8]. When working with multiple displays, a large context display and an additional personal mobile display, selection may be required in diverse scenarios of context and interaction.

To give the user more information before explicit selection, we show additional node attributes on the display wall for elements in close proximity to the user's focus (see Figure 1). This is possible as the system can estimate the user's position by tracking the mobile device in front of the display wall. However, as the user moves to explore the entire data space, different selection techniques are required both in close proximity and farther from the display wall.

While in close proximity, the user selects individual elements on the wall surface using touch. Furthermore, to select a group of nodes, the user can encircle the elements to select them (see Figure 2A) and thereby transfer them to the mobile display for further examination. Alternatively, instead of touch contact, also the corners of the mobile device could be used for contact with the context display [5]. However, to examine the entire information space the user will have to step back and move in front of the display. As a result, contact with the display surface is not always possible. The mobile display allows selection when farther from the display wall. We use pointing to select all elements within a rectangular area at the user's approximated line of sight through the mobile (see Figure 2B). This also supports easy selection of elements that would otherwise be difficult to reach at the top or bottom of the wall-sized display surface. Selection can then be refined by using touch to (de-)select elements. Associated elements on the display wall are selected accordingly and are available for further exploration on the mobile device.

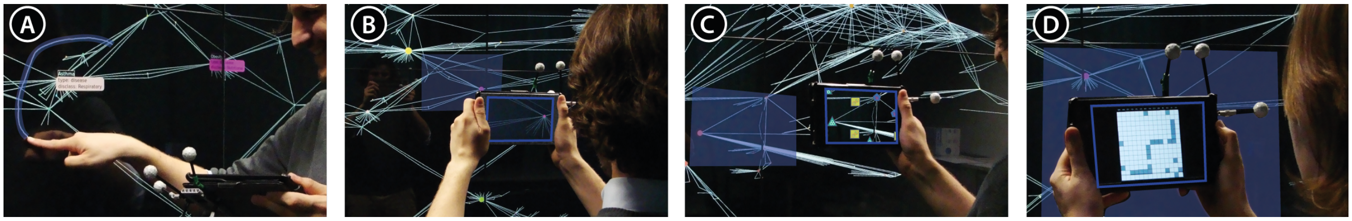

Figure 2: Users can select individual or groups of nodes by encircling elements on the display wall **(A)** or using perspective pointing from afar **(B)**. The mobile display provides a variety of lenses, including attribute lenses **(C)** and alternative representations of the selected sub-graph **(D)**.

2.2 Associated Details and Different Views

After the selection of elements the role of the mobile device changes. While the display wall presents an overview of nodes and their relations, the mobile device may display additional information and details associated with the selected content. Attributes of multi-variate data can be shown individually for every selected node or summarized for a group of graph elements as an additional overlay on the node-link representation of the mobile display or in a completely separate view on the device.

Taking this further, the mobile device may present alternative representations of the information space. In our implementation, we support visualization of the corresponding adjacency matrix to the subgraph in focus (see Figure 2D). This way, the user can benefit from the contrasting advantages of node-link and matrix representation, e.g., by manipulating edges in the adjacency matrix while examining pathways on the node-link visualization (cf. [3]).

2.3 Perspective Tangible Graph Lenses

Magic lenses are an established interactive tool for visualization with application for various data types and tasks [7]. They are an interactive focus and context technique and in traditional interaction can be moved within the information space to locally and temporarily add, enrich, or remove content within the visualization. Through the lens' properties (shape, size, position, orientation) a selection of the data is defined to be used as input for the lens function [7].

In our work, we bring the lens onto the mobile device where it can be controlled by the user as she moves within the space in front of the display wall. While the views are separated onto independent devices, we argue that this is still a focus and context technique [2], as the device's content (i.e., the lens) moves within the space in front of the wall-sized display (i.e., the context) so that the views merge from the user's perspective (see Figure 2C).

The selection is accomplished using basic pointing with the device (see above) and can also be frozen in space to further examine the content (similar to examples above tabletops [6]). While the device suggests a rectangular lens shape, the size can be manipulated when moving towards or away from the display wall, thereby selecting more or less elements. In this concept, input and output space merge as the user's movement of the display changes its visualization.

We implemented various lens functions for graph analysis, including basic magnification lenses, specific graph lens functions and attribute filters. These functions can be selected and adjusted using interface widgets on the mobile display and hence allow quick access to analysis tools even when far from the display wall. In particular, it is possible to select a specific layout lens to rearrange the selected region of interest on the mobile device and gain further information on the relations between nodes. Additionally, the selected nodes can pull in their neighbors onto the personal mobile view (for the specific lenses in literature cf. [7]). Furthermore, we implemented filters that highlight or remove different nodes according to their attribute values. For example, in the case of a graph presenting disease co-occurences, the mobile device can display the node-link representation in form of iconic images presenting the types of selected diseases for additional filtering (see Figure 2C).

The fact that the lens has only a localized effect further lends itself to use of the personal mobile device and multi-user scenarios. As a result of our concept, each user in front of the display can have her own personal view onto the data and collaborative data exploration sharing the same context visualization becomes possible.

3 Conclusion and Future Work

In this work, we presented concepts for graph exploration which illustrate the promising combination of mobile devices with wall-sized high-resolution displays. We analyzed common and recurring graph tasks and propose solutions in contact with the display wall as well as distant interactions. By tracking the mobile device in space, we enable interaction associated with specific data points on the display wall. We realized basic selection by picking from the large visualization and thereby transfer points of interest to the mobile device. This allows further examinations of multi-variate node data, detail views, and manipulation of attributes. To allow a personalized view onto the data, the mobile device becomes a perspective tangible graph lens containing custom settings per user.

In the future, we plan to specifically address the spatial components of this work focusing on the differences between absolute positioning in front of the display wall and the body-centric movements. Furthermore, it is necessary to extend our techniques to cover the entire process of graph exploration and manipulation. This could also include the analysis of pathways within the graph data and navigation in hierarchical graph structures (e.g., semantic clustering). In addition, we will investigate the application of our techniques to other visual representations and application cases.

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