Multiple Linked-View Exploration on Large Displays Facilitated by a Secondary Handheld Device

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ABSTRACT

Large displays are capable of visualising a large amount of data on multiple views including scatterplots and parallel coordinates and are often present in meeting rooms. They can be used to interact with a dataset and foster discussion among team members. Although some of these large screens have multi-touch capabilities, in many cases it is cumbersome to have to stand close to the display in order to interact with it. One of the solutions is to use a small handheld display to interact with the large display. This paper discusses how traditional interactions such as selection, brushing, and linking can be performed using a secondary handheld device. As a proof of concept, a system including scatterplots and parallel coordinates views is implemented. The interactions are straightforward and are useful for any interactive visual analysis application on a large display with wireless connectivity.

Keywords: Interaction, scatterplot, secondary device, high-dimensional visualisation.

1. INTRODUCTION

Information Visualisation (IV) is "the use of computer-supported, interactive, visual representations of abstract data to amplify cognition" [1]. *Visual Analytics (VA)* is defined by Keim et al. [2] as "the science of analytical reasoning facilitated by interactive visual interfaces". VA considers approaches and systems to help data analysts explore and make sense of large, complex datasets, often in a context of decision making and with a goal to find unknown patterns. IV can be thought of as the "frontend" of VA. Visual analytics systems combine approaches from fields such as Data Visualisation, Human-Computer Interaction, Data Analysis/Data Mining, User Evaluation, and Machine Learning. The applications of VA are many, including but not limited to multivariate data exploration on scatterplots (bivariate projections of pairs of dimensions) [3], interactive labelling [4] and subspace search [5].

Interaction an essential part of both IV and VA. In one of the early models for IV, Card et al. [1] describe visualisation as the "mapping of data to a visual form that supports human interaction in a workplace for visual sense-making". Although the concept of interaction in IV and VA has a long history [6], novel device and display technologies, and novel multimodal interaction possibilities [7] including gesture recognition, eye tracking, or data physicalisation offer new possibilities.

Visualisation techniques should be adapted according to the type of data, user task, and display medium. For example, scatterplots allow an analyst to quickly recognise patterns and relationships between any two of n dimensions of a multivariate dataset and have become a common technique for data visualisation of multivariate datasets. It is also possible to plot all the possible bivariate projections of a dataset, resulting in a matrix of n^2 scatterplots, called a *scatterplot matrix (SPLOM)* [8]. In a related technique, drawing all n dimensions as vertical axes next to each other and drawing each record as a polyline intersecting each axis, produces a chart known as a *parallel coordinates* plot [9].

Since both SPLOM and parallel coordinates charts aim to visualise the whole dataset in one view, a large number of pixels are needed on the screen, which motivates the use of larger displays. Such displays are commonly used in meeting rooms for decision making and presentation. Techniques developed by researchers to interact with large displays in VA applications include natural language [10], multi-touch [11], full body [12], and secondary handheld devices [13].

Each of these interaction modalities has strengths and weaknesses. Natural language is a powerful tool to interact with the screen from afar, but some tasks including data selection cannot easily be performed by this interaction alone. Multi-touch is another popular input modality, but may cause fatigue in a long meeting, since it requires the analyst to interact

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Figure 1: *The analyst in the middle is explaining the dataset on the large screen to other team members in a meeting. She is using a secondary handheld device to perform selection on an interesting part of the data.*

with the screen up-close. In such situations, using a handheld device connected wirelessly to the display can be a suitable option, visualising the data on the large display while at the same time giving analyst(s) the ability to control views and issue queries from a distance as well as up-close.

This paper describes how a multiple linked-view information visualisation application can benefit from adding a secondary handheld device as an additional controller for data exploration. In particular, it is shown how common VA techniques like brushing, linking, and querying can be facilitated using a secondary handheld device. This concept can be generalised to other multiple linked-view applications. Fig. 1 shows the implemented system being used in a meeting room.

2. RELATED WORK

Previous studies have shown that using a large display can foster visual analysis among small collaborative teams. Such displays are used for applications including sensemaking, classification, and scatterplot exploration [14]. Interacting with these displays is facilitated by various modalities ranging from direct interaction, speech, movement and use of additional devices.

Based on the concept of Regression Lens [3], Chegini et al. [11] introduced a VA application for exploring scatterplots on a vertically-mounted large multi-touch display. In this application, two users can collaborate on the same screen to perform regression analysis on a multivariate dataset. Direct multi-touch input is a reasonable choice, but the number of people who can collaborate on the same screen is limited. Moreover, using direct input on vertically mounted displays can cause the "gorilla arm" problem — a term used to explain the fatigue which sets in when users interact with their hands on a vertical screen for a prolonged period [15].

Natural language interaction is becoming a popular option to interact with systems. Srinivasan et al. presented Orko [10] – an application which facilitates visual exploration of networks. In Orko, users can directly search and perform queries through natural language interaction.

Using a secondary handheld device is another option to interact with a large display, especially in situations where interacting with the display up-close is not adequate. Tsandilas et al. presented SketchSliders [13] – a novel technique using a secondary handheld device as a sketching interface for exploring multivariate datasets on large displays. In other research, Kister et al. [12] designed GraSp – a set of spatially aware techniques for graph visualisation and interaction.

(a) *Scatterplot view on the secondary handheld display.*

(b) *Parallel coordinates view on the secondary handheld display.*

Figure 2: *Any view can be shown on the secondary handheld device to perform tasks such as brushing and linking from afar.*

Using these techniques, the analyst can explore graphs on wall displays by using a touchscreen on the secondary handheld device and body movement together with spatially aware mobile interactions. Later, Langner et al. [16] presented a coordinated views application which can be controlled by both direct multi-touch and one or more secondary handheld devices. However, the secondary handheld devices are purely used for input, not for output. In contrast, the system described in this paper uses a single secondary handheld device, but this device provides an additional view to the analyst as well providing interaction.

3. PROPOSED INTERACTION TECHNIQUES

It is becoming common for large displays to have wireless connectivity. Even without this feature, it is often possible to attach a wireless adapter to a monitor and then connect it to a secondary handheld device. In this paper, a 12.3-inch tablet (Microsoft Surface Pro, 5th Gen) is used as a secondary handheld device to interact with a large 82-inch 4K display with wireless connectivity (Samsung 88th series). Chegini et al. [11] previously presented a multiple linked-view analytical tool to find local patterns in scatterplots, which provides a SPLOM and scatterplot view. Users can select an area in one of the scatterplots and search for similar areas in the whole SPLOM. The system was developed for a large vertically mounted multi-touch display.

Recently, an additional parallel coordinates view has been added to the system. The system is also now dock-based, making it possible to detach any view and drag it to a secondary device. Moreover, it is possible to have two identical views – one on the large display and the other on the secondary handheld device – so that everyone in the room can observe how interactions with the handheld view are performed.

3.1 Brushing and Linking from Secondary Device

Brushing and linking are standard techniques for interactive visual analysis of large multivariate datasets [17]. They refer to the practice of selections (brushing) and changes (linking) in one view being simultaneously reflected in all other views. Collaborative brushing and linking ensures that interactions on the dataset by one collaborator are visible for everyone working on the data [18]. Therefore, in the presented system, if a user selects an area on a secondary handheld device using either a scatterplot or parallel coordinates view, the selected records will also be highlighted in the large display. For the other collaborators to have a clear understanding of brushing and linking procedure, the view shown on the secondary handheld device is always projected onto the main screen. This projected view includes both visualisations of the data and interactions performed on each handheld device. Fig. 2 demonstrates brushing and linking in scatterplot and parallel coordinates views.

(a) *A query performed on the secondary handheld device.* **(b)** *The query and its result on the large display.*

Figure 3: *The user can initiate a query on the secondary handheld device and visualise the results on the large display.*

3.2 Querying from Secondary Device

Another common technique in interactive visual analysis is to make a query after selecting an area in a view containing a set of records. In the system, the analyst can select an area in a scatterplot by lasso selection and then perform a search query to find similar areas in other scatterplots in the dataset. It is essential to visualise any such selections on the large display, so all collaborators in the meeting are informed about it. Therefore, an identical view on the large display shows the selection and parameters of the query issued on the secondary handheld device. Fig. 3 illustrates how a query on the secondary handheld device is visualised on the large display.

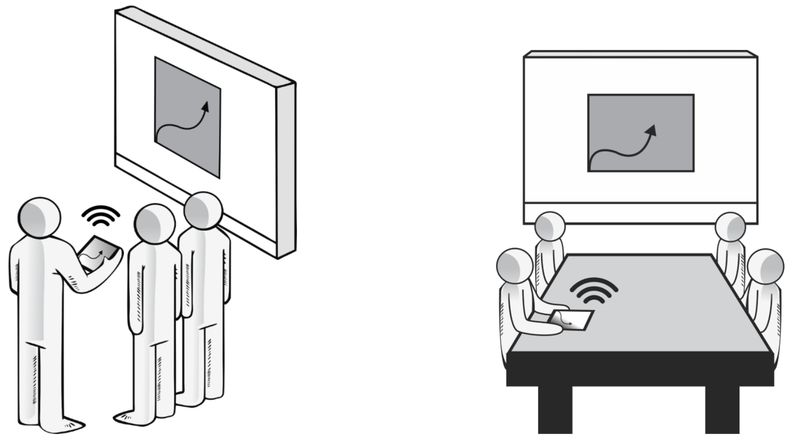
4. DISCUSSION

Preliminary experiments show that using a handheld device can be an appropriate proxy to interact with data visualisations on a large display, especially if several users are gathered around it. A secondary handheld device can be easily passed around for individual interaction, while the main display remains in sight. This is particularly useful for more detailed interactions, such as the specification of a query or the exact positioning of a regression lens widget [3]. A lightweight solution is possible using component-based application design in conjunction with the multiple-view desktop extension capabilities of current operating systems. Fig. 4 shows situations that can benefit from this type of interaction. A natural extension is to provide not one, but multiple secondary handheld devices for distributed, collaborative interaction by team members. To this end, a client-server implementation should be adopted.

Collaborative interaction for visual data analysis raises several interesting research challenges. For example, the server could track each members' data selection operations, and annotate them in the main display. The type of tracking and annotation is expected to depend on the analysis task. For example, when several experts collaborate to find local regression models in a given scatter plot, then each mobile display should show the current models proposed by the team members in a comparative way. Also, team members may interact with one another by passing and adapting each other's proposed regression models. Generally speaking, a collaborative visual analysis system should provide analysis provenance information, to allow comprehension of which operations have been performed by whom. Another interesting problem is to adapt the display shown on the mobile devices to the respective device characteristics, such as display size and resolution. Depending on the device capabilities, the presentation and interaction operations should be tailored to fit by adapting the amount of data displayed and possibly changing the visualisation metaphor used (semantic zoom).

5. CONCLUSION

There are various direct and indirect interaction techniques to explore multivariate datasets on a large display. In this paper, an affordable technique using a secondary wireless handheld device is introduced. By using this technique, the analyst can perform traditional visual analytics tasks including selection, brushing, and linking on a handheld device which



(a) *Meeting in front of the screen.*

(b) *Meeting around a table.*

Figure 4: *Two scenarios in which an analyst can pass over the secondary handheld device to other collaborators.*

is projected on the large display. As a proof of concept, the technique was implemented for exploring scatterplots in a multiple linked-view application.

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