Supporting Note Taking in Co-located Collaborative Visual Analytics on Large Interactive Surfaces

Narges Mahyar
Department of Computer Science
University of Victoria
nmahyar@cs.uvic.ca

ABSTRACT

My research examines how to support note taking in co-located collaborative visual data analysis. My preliminary observational study revealed the importance of note taking as one of the main analytical processes. This finding motivated me to further investigate note taking in the context of co-located collaborative visual analytics. I participated in designing and implementing CoSpaces, a tool specifically tailored for collaborative visual data analysis on tabletop displays. This tool provides a framework for collaborative data analysis, in which note taking mechanisms can be studied. Initially a simple note taking mechanism involving text notes recorded via an on-screen keyboard was implemented. However, a usability study found this to be insufficient. Because of my observation that users frequently used the automatically created links between notes and visualizations to access more information, I aim to investigate the effects of semi-automatic note taking mechanisms built into a collaborative visual analysis tool. I am planning to provide analysts with editable note-templates populated with information related to the current line of inquiry. I hypothesize that note-templates could improve the collaboration process by improving the structure of notes for group use. Evaluation will be done through qualitative user studies. Findings of this research will inform the design of future collaborative tools for visual analysis of data.

ACM Classification: H5.2 [Information interfaces and presentation]: User Interfaces. Graphical user interfaces.

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Keywords: Collaboration, Visual Analytics, Large Interactive Surfaces, Record-Keeping, Workspace, Awareness.

INTRODUCTION

Previous research has shown that Visual Analytics (VA) helps users to examine large datasets quickly and interactively [5]. In many domains such as business, users often need to work together to solve problems and make deci-

sions. Therefore, co-located collaborative visual analytics on large displays may offer new possibilities for analysts. Large interactive surfaces are known to encourage co-located collaborators to work in a more cohesive and productive way [12] compared to many other computing environments.

Collaborative analysis of complex datasets often happens over extended time periods or multiple sessions. Research shows that limitations of human working memory make it difficult to recall and connect previous findings and insights [14]. These insights need to be shared with others to assist with higher-level tasks such as decision-making and problem solving. Therefore, to help users remember, share, and make sense of their insights, researchers [6, 8, 9, 15] argue that there is a critical need to support insight externalization, through mechanisms such as taking notes, saving views of data, and annotating views.

Supporting note taking in co-located collaborative VA involves many challenges. What type of content is needed and how is it used? What is a convenient way to take notes when working with interactive surfaces? How should notes be shared among collaborators? How can both shared notes and private notes be handled by a system? How can the note taking process be streamlined? Although it is impractical to solve all of these problems at once, this thesis will identify many of the challenges around note taking in collaborative VA and investigate some of the issues in greater detail. Another contribution of this work will be providing general guidelines for supporting note taking.

OBJECTIVES

The goal of this research is to investigate how to improve support for note taking in a co-located collaborative environment involving large shared displays.

The agenda has been broken done into following steps:

1- (Completed) Performing an exploratory study of co-located collaborative VA to gain better understanding of the process and to identify promising research directions. This study identified the need for better note taking mechanisms, thereby helping to define the direction of the thesis.

2- (Completed) Implementing a base prototype system for collaborative VA on an interactive tabletop. Better note taking mechanisms will be added to this system so that I can examine the effectiveness of different note taking tools in co-located collaborative data analysis.

3- (Future) My current and future research aims at improving the prototype by extending note taking capabilities through design and implementation of a semi-automatic note taking approach, with pre-defined note templates to facilitate note taking in collaborative VA. These templates will be pre-populated with related information to the user's current line of inquiry. The source of this information is a user's own work as well as work done by other collaborators. I expect that these templates will help users to collaborate by fetching relevant information and/or creating links to the relevant notes taken by others.

Each of these steps is described in greater detail in later sections.

RELATED WORK
Note taking has been the subject of investigation in many domains such as education, cognitive psychology and visual analytics. From a psychological point of view, taking notes is a way of offloading cognitive processes and intellectual products such as insights, findings and hypotheses. It helps to build a "stable external memory" that can be used at a later time [1]. Furthermore, note taking seems to assist complex tasks such as problem solving and decision making by reducing the load on working memory. In the context of visual analytics, several researchers have mentioned the importance of note taking and annotation. Notes help analysts to think through problems and to remember previous findings and cues [11]. Furthermore, notes "act as a bridge between the analyses executed in the system and [a user's] cognitive process" [15]. Lipford et al. [13] stated that externalization helps analysts to "recall and discuss their rationale and decision points more confidently and clearly". Externalization refers to recording of insights in the form of notes, annotations and bookmarks.

Insight externalization has been implemented in several research tools. Sense.us [7] allows users to collaboratively analyze data, add annotations on top of a visualization, and write down their findings in notes attached to the visualization. Aruvi [14] similarly enables users to take notes and link related notes to each other and the visualization. HARVEST [12] automatically recommends notes most related to an analyst's current line of inquiry. Collaborative Annotation on Visualization (CAV) [3] allows analysts to remotely collaborate and add annotations on top of their visualizations. Some systems such as [2, 4] use templates to facilitate analysis and insight externalization. Note templates used in [2] reduce the effort required to take notes by pre-populating templates with important information. In addition, use of templates results in better structured notes that are easier to browse and retrieve. Gotz et al. [4] also use a template-based approach towards knowledge synthesis and recording insights and findings.

This research aims to extend the previous work to support collaboration. In particular, I aim to support note taking and note use in collaborative settings, and to explore how semi-automated approaches can be best extended to support group work. For example, pre-populated templates could automatically include content from other group members' notes. Such automatic links to relevant materials would create a network of recorded insights and findings instead of an unstructured collection of individual notes.

COMPLETED WORK
Step 1: Observational user study
I first conducted an exploratory user study [10] to understand how a group of data analysts behave and collaborate around a large interactive display while performing VA of tabular data. My observations emphasized the critical role that record-keeping plays in the overall process of collaborative visual data analysis. Part of my contribution was a collaborative data analysis framework that encompasses record-keeping as one of the main activities (for more details see [7]). Based on observations, I characterized notes according to their content, scope, and usage, and describe how they fit into a process of collaborative data analysis. One interesting observation was that notes differed depending on whether they were created for individual use or for group use. In particular, nearly all of the notes taken for a group had a recognizable tabular arrangement of content. This arrangement made the note easier to review by all group members at a later time. I also discussed suggestions to improve note taking functionality for co-located collaborative visual analytics tools. This study was instrumental in focusing the thesis on the support of note taking.

Step 2: Designing and implementing base prototype
One of the major challenges that we faced during Step 1 was that at the time there were very few applications exclusively designed for collaborative VA on large multi-touch surfaces. Therefore, following the study, we started designing a prototype system, CoSpaces, for co-located collaborative visual analysis of tabular data on large interactive surfaces (see Figure 1). A core design idea within CoSpaces is the tabbed Worksheet, a flexible work area that accommodates changes in the collaboration style and supports territoriality needs and flexible work organization strategies [13]. We have employed the tab metaphor acts as a channel for providing awareness. CoSpaces also incorporates a basic record-keeping mechanism that enables tracking of analysis history and note taking; such records are useful not only for managing individual analysis activities, but also for maintaining awareness of other users' activities.
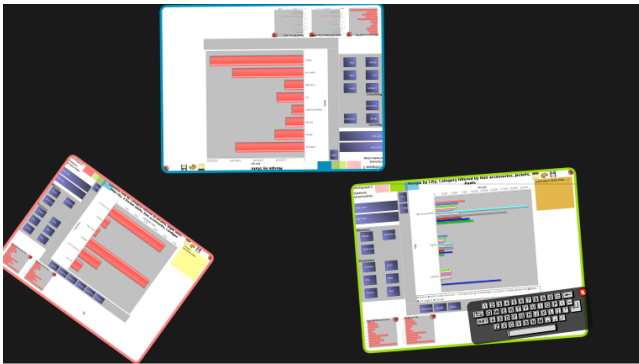
Figure 1: A snapshot of CoSpaces' user interface. Dark background is the common work area (tabletop surface). There are three open Worksheets where collaborators can simultaneously analyze data.
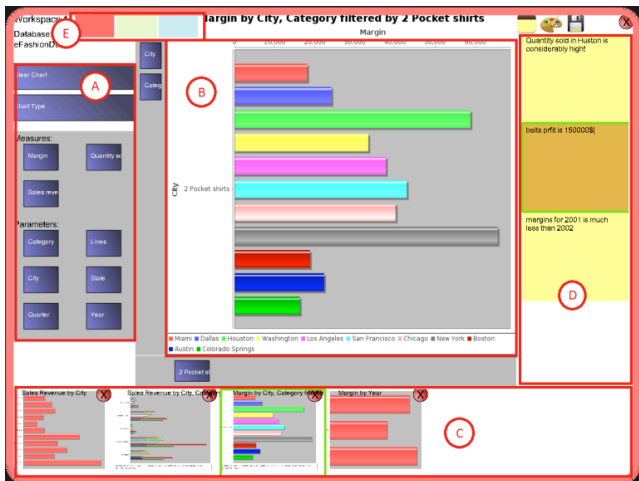

Figure 2: Detail of a Worksheet: Analysis pane (A), Visualization pane (B), History pane (C) Notes pane (D), and Tabs (E).

In the design of CoSpaces we paid careful attention to issues such as transient collaboration style, territoriality and providing awareness. Natural and fluid user interaction (drag and drop, zoom, pan and rotate by moving fingers) were implemented to correspond to the way that users expected a multi touch application would behave. A complete description of the prototype is beyond the scope of this paper. However, we draw particular attention to the record-keeping capabilities that are relevant to this thesis work. CoSpaces provides users with a thumbnail list of created visualizations (Figure 2, pane C) and a list of notes taken by the users (Figure 2, pane D). Each note is linked to its corresponding visualization and vice versa. Previous visualization states can be re-loaded by clicking on either a note or a visualization thumbnail. We also employed a tab metaphor as a way of providing awareness (Figure 2, pane E). Clicking each tab replaces a workspace's native view with the view of a remote workspace. This enables analysts to review each other's work without disruption.

To evaluate our prototype we ran a usability study. One goal of the study (and the aspect we will discuss here) was to examine how well a simple thumbnail history and notes pane could support record-keeping needs during collaborative analysis. Twenty computer science students (in the form of 10 pairs) took part in our study. We observed that many groups took notes (total of 71 times, by 8 out of 10 groups) and note taking mostly happened while working individually (loosely coupled work). On the other hand, referring to notes often happened when participants wanted to share their results (closely coupled work). We also observed that notes were often the first items to be studied when an analyst was reviewing a collaborator's work. However, note taking was a rather cumbersome process. The current note taking implementation was limited to the use of an on-screen keyboard for writing on basic post-it-like notes, and there were no advanced text editing capabilities or note templates. The simple on screen keyboard used in the studies was straightforward to use, but somewhat slow and awkward as an input mechanism. We speculate that this had a negative impact on the number of notes taken. In later versions of the prototype, we plan to address this limitation by providing a better input technique (e.g. physical keyboards or digital paper). However, we also postulate that taking and sharing notes may be easier with the addition of semi-automatic mechanisms; thus this is the focus of our next research step.

Step 3: Current and Future Work
During the usability study of CoSpaces, I observed that users found it cumbersome to take notes while working on a tabletop. In addition, participants found the linking between notes and related chart very pragmatic and useful. Therefore, as my next research step, I propose to facilitate note taking by designing and implementing a semi-automatic note taking module with pre-defined note templates into CoSpaces. In addition, by leveraging the collaborative setting, I plan to link new notes to all other relevant notes taken by other collaborators.

A note template would facilitate the act of note taking by providing users with a preliminary note that includes information about the current data view such as extrema values. Users can edit this note by adding their insights, findings and any other content. This would reduce the note taking burden by including important information. Moreover, having a template would lead to better structured notes that are easier to review and reuse later. Automatically creating links to relevant materials would create a network of recorded insights and findings instead of individual notes. This would help analysts to "connect the dots" that would improve problem solving and decision making. It could also facilitate searching for past materials (e.g. for inclusion in a report).

When an analyst decides to take a note, the system will provide a set of note-templates to choose from. A selected note-template could be pre-populated with information related to the current line of inquiry such as extrema values and mapping and filtering information [2]. The system could also automatically search for others' notes that might

be related to the analyst's current work [12]. These related notes could be used as part of a suggested note template.

I hypothesize that semi-automatic note taking could simplify the rather cumbersome process of taking notes on a tabletop. Subsequently, this could lead to a larger pool of recorded notes that would facilitate group discussion and promote collaboration. These speculations need to be studied in practice. Therefore, I will focus on investigating the effects of semi-automatic note taking on collaborative VA. Investigations such as the effect of semi-automatic note taking on collaboration style, number and content of notes, quality of the work outcomes (more complete reports, more findings in data, longer solutions, etc.) will be studied by running one or more user studies. Following each study, I would plan to refine the note taking templates.

CONTRIBUTIONS

So far, this research has identified several considerations for designing note taking mechanisms in collaborative data analysis tools. These considerations include enabling users to control the privacy level of notes, providing note sharing mechanisms, note manipulation and management. I also proposed a framework for describing collaborative data analysis activities. This framework incorporates recorded-keeping as one of the main activities performed during collaborative data analysis. Overall, this research aim to better support collaborative visual data analysis by facilitating note taking. I believe that investigating the effects of semi-automatic note taking on collaboration will inform the design of future collaborative tools.

Another contribution to the field is design of our prototype tools. In particular, CoSpaces introduced the concept of tab portal views that help to address the challenge of awareness, especially during periods of loosely coupled work.

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