History Tools for Collaborative Visualization

Ali Sarvghad, Narges Mahyar, and Melanie Tory

Abstract—In the context of collaborative data visualization and analysis, history tools can play an important role. We present a compilation that characterizes users’ probable objectives when using history tools for collaborative work, as well as operations commonly performed on histories. We further characterize user objectives according to the likely time/space setting in which they would be used, and whether they are likely to be used by individuals, groups, or both. We conclude by compiling a list of design and implementation challenges and research questions that need to be discussed and investigated in order to make history tools adequately support collaborative visualization activities.

Index Terms—History tool, collaboration, visualization, analysis.

1 MOST COMMON OPERATIONS ON HISTORY REPOSITORIES

Heer et al. [5] list a number of operations that a history tool should support. We built our list of operations largely based on their work, but we make some alterations. We expect the most common operations on history repositories to be:

- Browse
- Search
- Filter
- Edit
- Delete
- Export

We consider an editing operation to be changing the content of a history item, such as adding metadata, and we consider deleting history items to be independent from editing. We also consider searching and filtering as two different operations. Other researchers also point out the importance of browsing [3][12], searching [12][13] and editing [4] operations for history tools and some other researchers [4][8] mention the necessity of a tool to export and communicate history.

There is no one to one dependency between operations and user objectives. In other words, an operation, solely or in conjunction with other operations, can be performed to achieve a number of objectives. For example, searching and filtering both are required to accomplish analysis and validation objectives.

2 MOST COMMON OBJECTIVES

Based on a literature survey and our own experience, we expect history operations would be mainly used to achieve the following objectives:

- Analysis [3][8]: Users can traverse a history item repository and revisit different data visualizations to investigate data. Products of this analysis can vary from making a decision to verifying a hypothesis. We define analysis as investigating data with a specific goal in mind, in contrast to exploration.

- Validation [5][8][10][14]: Correctness and admissibility of decisions/findings or appropriateness of a single visualization can be examined by using history items. For instance, analysts may review visualizations created in the course of an analysis process to double-check that their findings are correct, or they may revisit a particular visualization to ensure that it is the result of correct mapping and filtering of data. This might be more helpful when users’ collaboration style changes over time such as autonomous collaboration. Participants may need to corroborate the outcomes on individual works that will be concatenated later.
• **Memory aid:** The limitation of humans’ short-term memory is a known fact, and a history tool can act as external memory aid [12]. Data analysts can add important notes, observations, calculations et cetera to history items for future referral.

• **Correction/Recovery:** If data analysts find their current visualization undesirable for any reason, they can perform a selective undo/redo from [3][5][8][11][13][5]. It is also possible to continue a visualization and analysis process from the last point in the history repository after a system failure.

• **Exploration:** Exploration involves investigating data without a specific goal in mind. Having a repository of history enables data analysts to try different courses of visual analysis by revisiting a history item and trying a different possible path. “Insight often comes from comparing the results of multiple visualizations that are created during the data exploration process” [2].

• **Reporting** [5][12]: A history repository, wholly or partially, can be sent to peers or upper management as a progress report, indication of the amount of work done, or formal report of findings.

• **Presentation** [5]: History items can be summarized and presented in a meeting situation. Presentation is similar to reporting, but typically occurs synchronously, as shown in Table 1.

• **Coordination** [4][8][11][12][14]: History items can help collaborators coordinate their effort by increasing awareness in situations such as autonomous collaborative work or remote synchronous/asynchronous situations. Also, viewing another users’ history can bring a person up-to-speed on the work done so far.

• **Training** [12]: Novice data analysts can learn from experts by reviewing the history of visualizations created and decisions made.

It is quite possible that users have a combination of objectives when working with history items. For instance, users might review visualizations created in the course of an analysis process to both ensure their validity (i.e. correctness/admissibility) as well as make a decision.

**Research** is an interesting additional objective offered by rich history tools. Researchers can survey users’ behaviour or assess a system’s usability by observing the history of analysts’ actions [5]. We do not include it in Table 1 because it is not performed directly by visualization users; nonetheless, it is worth mentioning.

### 3 Effects Of Time/Place Setting

Table 1 predicts the most likely time/place settings in which each objective might occur. As shown in the table, most of the objectives are likely to occur in all of the different time/place settings. However, we suspect that history records may need to be more explicitly displayed for synchronous distributed work in order to help users maintain awareness of others’ activities. Additionally, using histories in asynchronous work may require different functionality than synchronous work. For instance, when sharing a history with another user who will take over the work later, a person may want to highlight particularly important findings to ensure they are noticed, or remove an unsuccessful path of analysis and replace it with a simple note to say that investigating that direction was not fruitful.

### Table 1: Objectives' most likely time/place setting. ST = same time, DT = different time, SP = same place, DP = different place

<table>
<thead>
<tr>
<th>Objective</th>
<th>ST, SP</th>
<th>ST, DP</th>
<th>DT, SP</th>
<th>DT, DP</th>
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<td>Validation</td>
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### 4 Individual vs. Collaborative Use of Histories

Reporting, collaborating, coordinating and training are inherently collaborative objectives and require engagement of more than one person; the rest of the objectives could apply to both individuals and collaborating users. Though individuals and groups share most of the objectives, design of a history tool might need to be quite different to support the activities of a group as compared to one person. To adequately support group activities, we anticipate that history tools may need to provide the following functionality:

• **Representation of who** was responsible for each action recorded in the history.

• Both individual and shared histories. This will hopefully prevent users from being overwhelmed with history items from all members of the group. In addition, privacy control may be needed so that some items can be kept private.

• Additional awareness mechanisms, such as an indication that another user has worked on a similar chart or has looked at the same data. This might be similar to awareness mechanisms previously used in collaborative document search [9].

• Extensive editing, highlighting, and annotation capabilities. These will help users to communicate what they have done, or convert a history into a series of visual items and descriptions suitable for a report, presentation, or tutorial.

• Ability to export elements of a history to a document or presentation format for further manipulation.

### 5 Design Challenges/Questions

There are some important issues to be considered in designing and developing history tools. These issues need to be resolved before history tools can effectively support collaboration:

**What content should a history item contain?** Researchers have suggested and examined a variety of probable contents such as user interactions (or commands) [3][15][17], software states [5], a combination of commands/states [13] and states plus users’ augmented information [5]. User information (which user was responsible for each action) may also be needed for collaborative objectives such as coordination. However, it is still unclear exactly which content is needed to support different collaborative tasks (e.g. training vs. shared analysis) and collaboration styles (e.g. loosely coupled to closely coupled work).

**What data structures should be used?** Histories can rapidly grow in size and need appropriate data structures and scaling tools [5].

**How should a history be represented?** Selecting the form that best suits users depends partly on form of the content [5]. For instance, a repository of executed commands can be represented as list of textual commands, a history consisting of a number of graphs can be represented as a comic strip [7], and for hybrid content of commands/states, text and graphics can be used jointly [13]. The ideal representation will also depend on the task, display and input hardware, and setting. For instance, a history that can
support distributed awareness during joint analysis may look very
different from a history that can support co-located training.

**How can we support fluid interaction with histories?**
Especially for co-located collaboration, where interactive touch
surfaces may be used, new mechanisms may need to be developed
for interaction with histories.

**What are underlying data challenges?** It is important to pay
attention to the underlying data. Volatile or streaming data add
additional challenges for history tools [5]. Moreover, we might
need to closely survey different data (e.g., business data and
scientific data) to understand their effect on content and
representation of history repositories and functionalities they
should provide to facilitate collaborative work.

**What features of a history tool are needed to support
different collaborative activities?** Can a single architecture
support all of the different time/place settings and user objectives?

## 6 Conclusion

In this paper we compiled a list of operations and objectives related
to history tools, and described the importance of such tools for the
process of collaborative data visualization and analysis. History
tools to support collaborative work are not merely instruments for
correcting errors but also provide users with some vital functionality necessary for coordination, training, sharing
information, and many other objectives. Designers of software for
 collaborative work need to take into consideration operations that a
history tool must support and objectives that users are most likely
to desire. Open research questions include what content to include
in histories, how to store histories efficiently, and how histories
should be best represented to support different collaborative tasks
and situations.

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