

# Interaction Log and Provenance for Sensemaking

Phong H. Nguyen, Kai Xu, B. L. William Wong

## ABSTRACT

This paper describes two visual analytic tools designed to support sensemaking through the visualisation of interaction log and analytic provenance. The first tool, SensePath, aims to reduce the time required for the transcription and coding during qualitative analysis such as thematic analysis (making sense of the experiment data). The second tool, SenseMap, is designed to help online sensemaking with everyday tasks such as buying a digital camera. User evaluation leads to early insight of how the visualisation of interaction log and analytic provenance can help these sensemaking tasks.

**Keywords:** analytic provenance, sensemaking, visualization, interaction logs

**Index Terms:** K.6.1 [Management of Computing and Information Systems]: Project and People Management—Life Cycle; K.7.m [The Computing Profession]: Miscellaneous—Ethics

## 1 INTRODUCTION

There are many possible applications of interaction logs, and we are particularly interested in supporting sensemaking. In this paper, we describe two visual analytics tools designed to support sensemaking with the help of interaction log, which we call *analytic provenance*.

Sensemaking is the process of comprehension, finding meaning and gaining insight from information, producing new knowledge and informing further action [11]. It is the construction, elaboration and reconciliation of representations that explain the information we receive about the world [6]. The outcome of the sensemaking process is important, but the process itself also contains valuable information [10]. Analytic provenance captures both low-level user interaction with visual exploration systems and high-level user reasoning process. It supports reproducibility, accountability, training, collaboration and can help us understand what we can trust from possibly uncertain data [12].

Given the rapid increase in data volume and complexity, more tools are needed to support sensemaking, which in many cases remains a slow and laborious process performed by human analysts. The design of such tools requires a deep understanding of the sensemaking process, which is a reoccurring goal of qualitative research conducted by many HCI researchers. Common methods for such qualitative analyses are grounded theory [3] and thematic analysis [5]. Typically, researchers need to design a study, collect observation data, transcribe the screen capture videos and think-aloud recordings, identify interesting patterns, group them into categories, and build a model or theory to explain those findings. Unfortunately, this process largely remains manual and thus very time consuming. Thus, the first tool we development, SensePath [9], is designed to help this process, supporting the transcription and coding of the observation data of online sensemaking.

Another common issue in sensemaking is that people often get lost when solving complicated tasks using big datasets over long periods of exploration and analysis. They may forget what they have done, fail to find the information they have discovered before, and do not know where to continue. In the World Wide Web context, this is known as the *disorientation* problem [2]. One approach to address this problem is through a graphical browser history [7]. It visualizes visited web pages and the linking relationships between them to help

users to quickly see where they are in the network and to navigate to the page they want. However, when solving a sensemaking task online, which requires gathering, restructuring and reorganizing lots of information to gain insight, the disorientation problem becomes more severe and difficult to address. They do not just get lost in the hypertext space but also get lost in the task space. Our second tool SenseMap [8] captures the sensemaking process (through interaction logging) and provides an overview to support information collection and curation.

## 2 SENSEPATH

First, we conducted two sets of observations to understand the characteristics of qualitative analysis of sensemaking activities. The insight from the observations led to the design user requirements for our tool. We decided to support qualitative researchers in using thematic analysis, specifically to improve the efficiency of its transcription and coding stages. Other requirements can be found in the original paper [9].

Our tool – SensePath – is implemented as a Chrome extension consisting of two components. The first one is a background process running in the participant’s browser to automatically capture all the required analytic provenance during the observation stage of the qualitative study. The second component includes a set of four linked visualizations of the captured provenance data (Fig. 1), designed to facilitate transcription and coding.

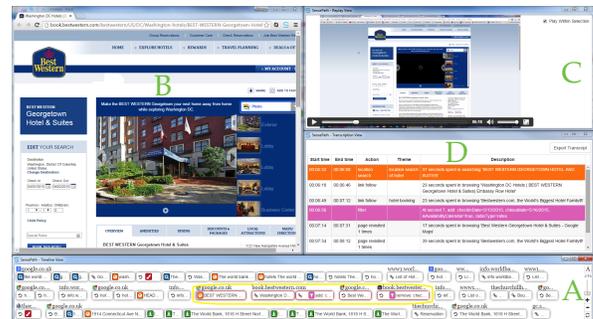


Figure 1: Four linked visualizations of SensePath. **A:** The timeline view shows all captured sensemaking actions in temporal order. **B:** The browser view displays the web page where an action was performed. **C:** The replay view shows the screen capture video to provide additional context. **D:** The transcription view details selected actions (highlighted in the timeline) and generates their transcript.

### 2.1 Interaction/Provenance Capture

We capture the analytic provenance corresponding to the *action* level in the Gotz and Zhou’s model [4]. This capture can be done automatically yet still provides reasonable amount of semantics to the researchers. The following four aspect of actions are captured.

- **Type:** The type of action such as *search* and *filter*.
- **Timing:** The start and end time of an action.
- **Context:** Page title, URL, screenshot and contextual information such as “keyword” for search and “selected text” for highlight.

- **Relationship:** Providing how a web page was activated including *revisit* an already opened page, directly *link* from an existing page, manually *type* a new address, and open from a *bookmark*.

## 2.2 Timeline View

This view provides an overview of the entire sensemaking process, showing all the captured actions in their temporal order (Fig. 1A).

An action is represented as a bar, presenting all four aspects of provenance information discussed earlier (Fig. 2). The page URL (context) is displayed atop the bar. In the bar, the first icon shows that this action revisited a previously opened page (relationship). Next is the page title (context); only part of which is shown because of the limited space. This is followed by an icon indicating the type of that action such as a “filter”. The last part is the specialized context for each action type, which is filtering parameters in this figure. The width of the action bar corresponds to the length of time spent in browsing the web page, and the relative position of the action type icon marks when the action happened.



Figure 2: An action bar showing all four aspects of provenance information.

**Zooming** Action bars can reduce their widths through zooming to accommodate more actions. At the smallest level, only the action type is visible, and more details will become available when zooming in. Fig. 3 shows three zoom levels of action bars with the details increasing from top to bottom.

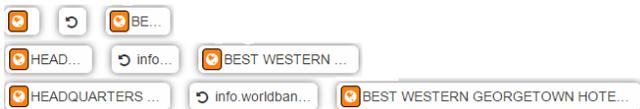


Figure 3: Three zoom levels of action bars with the details increasing from top to bottom.

**Aggregate Action** Instead of showing individual actions, adjacent ones happened on the same web page are merged to save space. It may also help researchers quickly understand the participant’s process. Fig. 4 shows an aggregated action with eight highlights, which were made on the same Google Plus page.



Figure 4: An aggregate action bar. It combines eight adjacent highlights made on the same Google Plus page.

Because the action bar is short, a timeline can show multiple rows. This, in combination with aggregation and interaction (described next), allows SensePath to display a reasonably large sensemaking session within a limited space. Fig. 1A shows about 50 actions out of a total of 70 actions from a 30-minute long session.

**Selective Zooming** SensePath implements focus+context technique [1] through *selective zooming*: when a zoom is executed, only a selected set of actions affects. This enables researchers to concentrate on certain actions without losing their context. However, they may forget the difference in zoom levels of actions, thus misunderstand

the action lengths indicated by the bar widths. SensePath provides a reset button to change the zoom levels of all actions to the default value. Fig. 5 illustrates this technique.



Figure 5: Selective zooming. Selected action bars are with red borders. Top row: before zooming. Bottom row: after zooming – only the selected action has its zoom level changed.

**Filtering** Researchers can filter actions based on duration, enabling them to focus on the range of actions they want. For example, if researchers think actions that last only a few seconds are trivial, they can be filtered out using a slider (Fig. 6), which sets a minimal length for visible actions. When the slider moves, actions that will be removed fade out, before disappearing when the slider stops. This enables researchers to preview the effect of filtering.



Figure 6: Actions filtering. The slider (on the right side) controls the minimal length visible actions. Actions fall below the threshold fade out first before completely disappearing.

**Coding** In traditional qualitative analysis, researchers analyze transcripts to identify common themes and assign suitable names or codes to them. In SensePath, the timeline view provides a succinct summary of the sensemaking process and allows researchers to drill down to explore more specific actions. Representing action types with icons and visualizing a sequence of actions next together may also help researchers to quickly identify patterns of the data, compared to watching videos or reading transcripts. Coding feature is available through a menu button when hovering an action bar.

## 2.3 Browser View

When an action is selected in the timeline, its associated web page is showed in the browser view (Fig. 1B). This enables researchers to examine the web page that the participant was looking at when performing a sensemaking action. If the action is an annotation or highlight, the browser view will automatically navigate to the location of the web page where the annotation or highlight was made, informing researchers which part of the page the participant was interested in.

## 2.4 Replay View

SensePath links the timeline to an externally captured screen video to provide additional information about the participant’s behavior during the sensemaking session. When a researcher selects an action in the timeline, the replay view automatically jumps to the corresponding part of the screen video when the action is about to start. This avoids manual search within the video, which can be time consuming. After selecting an action in the timeline, a researcher can first check the web page in the browser view and then start the video playback in the replay view if she wants to find out more. The playback automatically stops when it reaches the end of an action, avoiding watching other irrelevant part. Alternatively, the researcher can choose to allow the video to continue; if so, the corresponding action in the timeline will be highlighted as the video progresses.

## 2.5 Transcription View

Detailed information of an action can be revealed by mouse over; however, it is inconvenient to do so for a set of actions. The transcription view addresses this issue by simultaneously presenting the details for all selected actions, in a tabular format (Fig. 1D). For each action, this view shows its starting and ending time, action type, assigned themes, and an automatically generated description such as “37 seconds spent in searching Best Western George Town Hotel and Suites”. This description is based on a predefined template for each different action type with advice from the aforementioned participatory design session. The researchers are allowed to edit the description to better reflect what they think. Row backgrounds match the color of action type icons in the timeline view. The design of this view resembles the transcript interface of popular video transcribe software packages to reduce the learning efforts required.

## 2.6 Evaluation

We conducted a user-centered evaluation of the SensePath tool to establish an understanding of its use by an experienced qualitative researcher. We first conducted a number of user studies of participants carrying out an online sensemaking task, and we then recruited an HCI researcher with 7 years of experience in qualitative research to carry out an analysis of the sensemaking process of the users using SensePath. The researcher found the tool intuitive to use. The timeline view provided a useful overview of the participant’s sensemaking process, enabling her to quickly identify recurring patterns of the participant and his rough strategy in conducting the task. The replay view complemented the timeline view with screen recording, enabling the researcher to investigate more fine-grained and continuous interaction.

## 3 SENSEMAP

While SensePath targets HCI/Visualisation researchers, SenseMap is designed for average users and everyday sensemaking tasks. To understand the requirements, we first conducted a semi-structured interview with nine participants to explore their behaviors in conducting online sensemaking for their daily work activities. These behaviors led to a sensemaking model for user behaviors on the web: users iteratively *collect* information sources relevant to the task, *curate* them in a way that makes sense, and finally *communicate* their findings to others. This is a simplified version of Pirolli and Card’s sensemaking model [11]. We conducted a series of design workshops to derive requirements using these user behaviors and model and discuss design options to address them. All the requirements can be found in the original paper [8].

SenseMap is implemented as a Chrome extension with three linked views as show in Fig. 7.

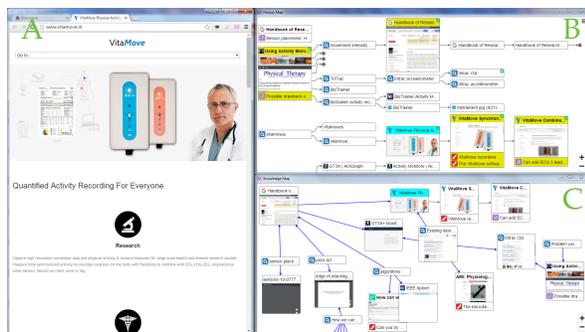


Figure 7: Three linked views of SenseMap. **A:** This is the standard browser with additional sensemaking and provenance support. **B:** The history map captures and visualizes user actions to provide an overview of the sensemaking process. **C:** The knowledge map enables users to curate and make sense of the most relevant information to their tasks.

## 3.1 Browser View

This is a standard web browser with additional sensemaking support such as highlight and annotation (Fig. 7A). User interaction is also captured using the same mechanism discussed in Sect. 2.1.

## 3.2 History Map

This map provides an overview of the sensemaking process using the captured actions and their provenance (Fig. 7B). An action is represented as a bar with an icon indicating its type and text showing the contextual information similarly to Fig. 2. Highlights and annotations of the same web page are grouped together as in Fig. 8. They are located in separate rows below the web page title. By default, just a few highlights and annotations are shown to ensure a reasonable height for the page. All of them can be revealed using a menu available when hovering on any highlight or annotation.

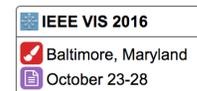


Figure 8: A page with one highlight and one note.

To help provide a connection between the history map and the browser view, the action bar corresponding to the active browser tab is highlighted in cyan. Pages that have been opened but have not seen yet (could be the result of opening links in new tabs) are shown with a dashed border, which may help to remind the user on reading them. Fig. 9 shows an example of pages with these two states.



Figure 9: The user is active on a search result page (left bar) and opens a link in a new tab (right bar).

The history map displays all captured actions; however, probably not all of them are equally important and relevant to the sensemaking task. Therefore, it is necessary to allow users to assess the relevance of the collected information. We use the term *node* to refer to either a simple search action bar or a page containing many highlights. Three levels of relevance are provided, all through the menu available when hovering a node.

1. If a node is completely irrelevant, the user can *remove* it.
2. If a node is not quite relevant but the user wants to keep it to have a look at some point, they can *minimize* it.
3. If a node is very relevant, the user can *favorite* it.

When a node is removed, it and its links are removed from the map. When a node is minimized, it is collapsed into a small circle. This enables users to focus on other nodes and also save the display space. Favorite nodes are displayed with a yellow background and a thumbnail of the captured screenshot to increase their recognizability. Fig. 10 shows an example of minimized and favorite nodes.

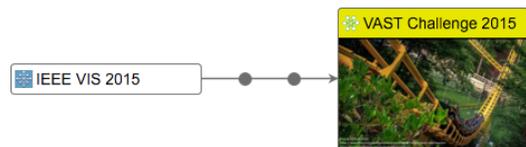


Figure 10: Nodes are pre-curved: two irrelevant nodes in the middle are minimized, whereas the last one is set favorite.

Nodes can reduce their size through zooming to accommodate more nodes within the visible part of the history map. By default, all

nodes have the same width and the same maximum height, which allows a few words of the contextual text visible, and a reasonably large thumbnail image, which may help users recognize the visited pages. For each smaller level, both the node width and the number of highlights are reduced. The maximum height should be adjusted so that the ratio between it and the node width remains unchanged. At the smallest level, only the action type icon or a small thumbnail image is shown. Fig. 11 shows an example of different zoom levels applied onto the same node.



Figure 11: The same node with four zoom levels.

Node zoom level is explicitly controlled by the user using simple plus/minus buttons. When the collection of nodes exceeds the visible area, the user can pan the map to see them.

### 3.3 Knowledge Map

This map allows users to curate the information displayed in the history map (Fig. 7C). The curation process starts by adding nodes from the history map to the knowledge map. This is done via the *Curate* button in the menu available when hovering over a node. Nodes in the knowledge map have the same visual representation with those in the history map. The only difference is that thumbnail images of curated nodes are always made visible to improve their recognizability.

The limit of single dimensional ordering tabs from left to right is addressed in the knowledge map through the spatial organization of nodes. The user can freely move nodes by simply dragging them around. This enables the user to spatially group nodes and to assign different meanings to them. Fig. 12 shows an example of a knowledge map with three clear groups based on their locations.

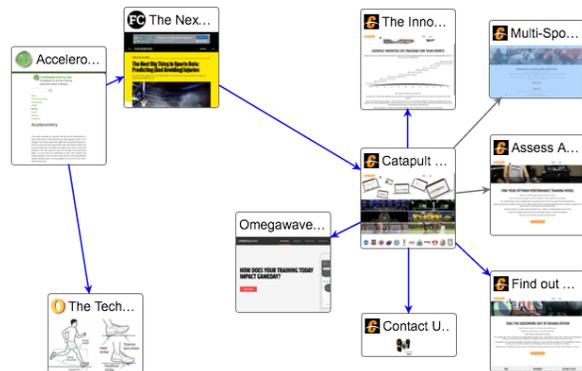


Figure 12: A knowledge map with three clear groups of nodes as the result of free movement.

Besides spatial grouping, seeing the casual relationships between collected information is also important to users in supporting sensemaking. A conventional representation is used to show this relationship: an arrow pointing from the cause to the effect. The user can add a casual relationship by clicking on the “cause node”, holding it for half a second until the cursor changes to an arrow, then releasing the mouse on the “effect node”.

When nodes are added to the history map, the provenance links among them are also copied to the knowledge map to provide an

initial understanding of existing relations. Different colors are used to distinguish user-added links from provenance links.

Currently, SenseMap does not provide support for any formal argumentation methods. However, we think that the flexibility of spatial organization and relationships establishment can help the user apply their reasoning strategies. For instance, users can draw a link from a “hypothesis” node to its evidence. Then, they can move all supporting evidence nodes to one area and all counter evidence nodes to a different location to distinguish the two groups.

### 3.4 Communication

The final organization of curated information provides a complete picture of solving the sensemaking task, which makes it ideal for the user to present their findings. If the process is of interest, the history map can be used alongside the knowledge map. Moreover, the user can refer to raw data, via node revisitation, to support their presentation.

Both the history and knowledge maps can be saved as local files and loaded. This allows users to share their maps. Also, the user can create multiple copies of knowledge maps based on the same history map allowing customizing for various presentation purposes.

### 3.5 Evaluation

To explore how SenseMap is used, we conducted a user study in a naturalistic work setting with five participants completing the same sensemaking task related to their daily work activities. All participants found the visual representation and interaction of the tool intuitive to use. Three of them positively engaged with the tool and produced successful outcomes. It helped them to organize information sources, to quickly find and navigate to the sources they wanted, and to effectively communicate their findings.

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