Logging in Visualizations: Challenges of Interaction Techniques Beyond Mouse and Keyboard

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Abstract

Due to the deployment of novel interaction techniques, additional challenges for logging purposes in information visualizations arise. In this position paper, we discuss specific challenges regarding four different example setups illustrated with projects of our own. In each setup, various aspects need to be considered to enable, e.g., a meaningful logging of (multiple) input streams or the replaying of logs. We do not aim to provide a technical solution for logging interaction in the various setups, but rather want to share our insights and experiences from a set of projects that apply novel interaction techniques and multi-display setups to visualizations.

1 Introduction

As an ongoing upward trend in research, various novel interaction techniques are deployed to information visualizations and enhance the way we work with those visualizations [5]. Through the usage of additional modalities (e.g., touch, gaze, spatial position) or multi-display environments, the visualization systems are getting more complex. Of course, this also affects the logging of interactions and raises several questions, such as: What data can be logged and in which form could it be stored? What data has to be logged to allow making sense of the logs at a later time? How to handle large amounts of data and noise?

In this position paper, we aim to raise awareness of these challenges by considering four example setups using various input modalities. Although the given questions are also relevant in classic WIMP interfaces, the capturing process itself is in such systems relatively easy as there is typically a single event source. Also, it is possible to replay or simulate user interactions, since they do not depend on an outer context. In contrast, enabling novel interaction techniques causes more complex setup-driven challenges to arise. We provide four of our own projects going beyond WIMP interfaces to discuss the specific challenges of logging when merging multiple input streams, the possibility of replaying logs for interpretation, and the complexity and size of logged data.

2 Touch Input

We previously presented several multi-touch concepts to enable fluid interaction for star plot visualizations [4]. This involves rearranging axes via drag (Fig. 1a), splitting up axes on double-tap (Fig. 1b), scaling axes via pinch, or resetting the visualization via a wiping gesture. Thus, the interaction comprises single-touch, multi-touch, and gestural input.

Regarding the logging, single-touch as well as some multi-touch inputs (e.g., two finger drag) can be treated similar to mouse input in classic WIMP interfaces: They can be discrete events (e.g., tap) fired on a specific visualization element or continuous events (e.g., drag). For the latter, the interaction can be logged with all individual events, selected events (i.e., sub-steps), or as a single event. This consideration affects how granular a history or replay functionality can be realized.

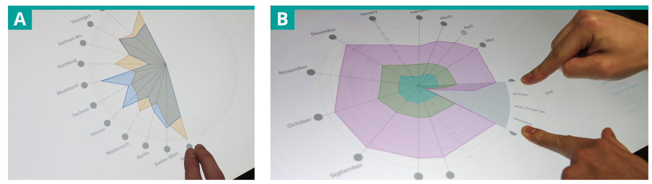

Figure 1: Fluid multi-touch interactions for star plot visualizations [4] require logging of both discrete and continuous input events (e.g., tap, drag).

In contrast, touch interactions like pinching have two or more input points defining a parameter (e.g., scaling factor) and the target. These multiple event sources require synchronized time stamps or storing as a combined event. Again, the granularity of stored (sub-) events can vary. Finally, gestural inputs (e.g., wiping) consist of a sequence of events from one or multiple input points, which are recognized as discrete gestures by the system. Therefore, they can either be logged as the recognized gesture or as the event sequence, which however requires the same gesture detection at the time of replay.

3 Spatial Arrangement of Mobile Devices (2D)

In a second example focusing on spatial interactions, we investigated how visualizations in multiple coordinated views can get tangible by distributing them to mobile devices [3]. We propose to use the spatial arrangement of these mobile devices to combine different visualization views and thus to enhance, e.g., visual comparison. For instance, this can be reached by reordering elements, flipping the view (Fig. 2a), or scaling of axes (Fig. 2b).

Figure 2: When adapting and synchronizing tangible visualization based on the spatial arrangement of mobile devices [3], individual data streams have to be joined for logging.

Besides keeping track of interactions on each device, it is now also necessary to know the applied combination or linkage of visualizations (similar to multiple coordinated views). Hence, the visualization state can now also depend on the state of other visualizations. This can be tracked by either logging the computed state as well as updates for each visualization or the initial state combined with linkage information. The deriving challenge for logging is to decide how to record this state, thus balancing between amount of stored data and how easily logs can be restored.

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Furthermore, as the setup is also extended by a new modality, the spatial arrangement of devices, it is necessary to log the device location (position and orientation). The required values can be distributed (i.e., provided by the devices) or centralized (i.e., provided by an external tracking system) and be relative or absolute. Whereas relative values require to store pairwise relations to be able to reconstruct the device locations, the absolute values require calculation steps during restoring. In both cases the provided values can be noisy and high-frequency, resulting in a large amount of data to be logged. For instance, logging 3DoF (4 Byte per float value) with 60 Hz tracking frequency already results in 720 Byte per second per device that can significantly increase further depending on the logging format (e.g., XML syntax).

It is important to be aware of the fact, that logs cannot be equivalently replayed in such a setup as devices would have to be moved automatically. Furthermore, since the combinations also utilize device properties (e.g., size), the system state cannot be transferred to other setups with different devices. Although it is possible to virtually simulate the devices and their content on a larger display, the tangible characteristic of the interaction concept would be lost.

4 Spatial Navigation with a Mobile Device (3D)

Instead of arranging mobile devices on a 2D surface, we also investigated the combination of wall-sized high-resolution displays with spatially tracked mobile devices for graph exploration in a 3D space [1]. Our concepts focus on supporting selection, presenting additional information, or applying lens functions (Fig. 3). By tracking the device's position in space, the system can associate the user's actions with the device to individual graph elements presented on the display wall.

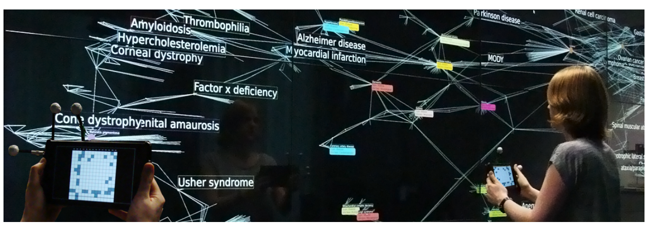

Figure 3: When using mobile devices for focus views in front of large wall-sized displays [1], all log events must retain their relation to the wall-sized visualization.

Similar to the example in 2D space, the mobile device's location (3D position and orientation) is essential for the logging process. However, the state of the current (part of the) visualization on the mobile device largely depends on the relative position to the visualization on the large display as they function as focus and context. Hence, to create a meaningful log, captured visualization states on the individual displays need to be fundamentally interwined and cannot be separated. Furthermore, touch interaction on the mobile device may manipulate and locally affect the visualization on the large display wall. Similar, interactions with the mobile device (both the simple presence/position and mobile device gestures) will have to be logged in relation to elements on the display wall. Complexity increases when multiple people (and devices) move in front of the display.

While individual touch events on both displays and the tracking data stream from the mobile device can be replayed from the logs, the impressions, the user's individual view on both the mobile device and the display wall, and the situation setup cannot be restored without active reenactment.

5 Body-centric Physical Navigation

In BodyLenses [2], we explore the design space and usage of body-centric movements for interactive visualization lenses. In the application example of a graph explorer, we used the body position and shape (tracked by a Kinect) in front of a display wall to apply lenses onto a graph visualization (Fig. 4a). These lenses can be further configured through touch interaction on the display wall (Fig. 4b).

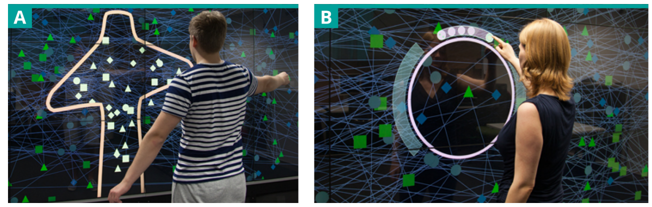

Figure 4: Body-centric interactions may require logging of individual body parts. These interactions can be used to influence tools on large display visualizations, e.g., interactive lenses [2].

Body-centric interaction may require tracking of not only one single position but the positions of multiple body parts (e.g., hands, head, arms, legs). The sum of these joints are skeletons already extracted from the Kinect video data stream. While event-based gesture recognition can be handled similar to mouse or touch-based interpretation, the adaptation of visualization or interactive tools like lenses requires continuous position data. This tremendously increases the size of the logged data and requires additional thought of which frequency and granularity is required for logging. Due to the highly personal shapes, restoring the data from the logs is even more complex and replay is nearly impossible.

6 Discussion & Conclusion

As illustrated by our examples, one major challenge when logging interactive visualizations in novel display environments is to handle the various input streams. The synchronization of these individual streams may be already difficult, and even more so when no central server organizes communication. Besides the need of synchronization, each stream can be high-frequent with multiple DoF and thus result in large log files. Therefore, it is important to consider filter mechanisms that are able to remove noise as well as unnecessary data (e.g., unchanged positions). An additional way to reduce the data amount is using delta encoding, i.e., only the changes are being logged. However, these can increase the complexity when restoring or analyzing the logs.

Since in our projects we incorporate physical interactions (e.g., spatial position or arrangement), providing a history or a replay functionality based on the logged data may not be possible. This is a crucial drawback of replaying, as the interaction order as well as the specific arrangement, position, or field of view of users during the interaction steps might affect the number, type, and quality of insights. Furthermore, in some cases it may not even be possible to internally log all user interactions (e.g., point of view, conversations) requiring extra video recording. As stated before, a session could be replayed in a pure virtual way, probably even in VR environments, but would still lack the important immersion during interaction.

All in all, novel interaction techniques come along with new challenges for logging in visualizations, especially regarding handling of input streams and providing the possibility of replays. Besides the used modalities in our example projects there exists many more (e.g., pen, gaze) that, however, face the same challenges. In the future, modern technologies such as augmented/virtual reality could even require additional considerations when enabling everywhere or immersive information visualizations. At the same time, logging these novel interactions and analyzing them afterwards could enhance our understanding of how people read visualizations on their own or discuss them during collaboration. Of course it is also an interesting challenge to find appropriate visualizations to support gaining these insights.

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