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Sketcholution: Interaction histories for sketching ☆

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ABSTRACT

We present Sketcholution, a method for automatically creating visual histories of hand-drawn sketches. Such visual histories are useful for a designer to reflect on a sketch, communicate ideas to others, and fork from or revert to an earlier point in the creative process. Our approach uses a bottom-up agglomerative clustering mechanism that groups adjacent frames based on their perceptual similarity while maintaining the causality of how a sketch was constructed. The resulting aggregation dendrogram can be cut at any level depending on available display space, and can be used to create a visual history consisting of either a comic strip of highlights or a single annotated summary frame. We conducted a user study comparing the speed and accuracy of participants recovering causality in a sketch history using comic strips, summary frames, and simple animations. Although animations with interaction may seem better than static graphics, our results show that both comic strip and summary frame significantly outperform animation.

1. Introduction

Sketching is commonly defined as rapidly created freehand drawing that is not intended to yield finished work, but rather to visually explore ideas (Ullman et al., 1990), and is a common tool for early design and creativity, regardless of discipline (McKim, 1972). While pen and paper remain the most common medium for such activities, digital media for sketching has several compelling benefits beyond paper. One such is the ability to capture not just the final state of a sketch, but also every intermediate state along the way. Based on this idea, we propose *Sketcholution*, an automatic visual interaction history of how a sketch has evolved over time (Fig. 1). Whereas a paper-based visual history would require the designer to take regular photocopies or digital pictures of the sketch being worked on, Sketcholution runs unobtrusively in the background of the digital sketch tool, capturing every single stroke made by the designer. This interaction history can then be played back, stroke by stroke, to show how the sketch was created and evolved over time. This would allow the designer to, for example, recall progress made during an earlier sketch session, communicate a particular idea to a collaborator or a stakeholder, or access an earlier version of a sketch to either revert to or fork from that version (similar to source control systems).

Animation with interactive control is a seemingly obvious choice over static representation given that animations have been shown to improve understanding of spatiotemporal information (Rieber, 1990; Zhu et al., 2011). However, merely playing back an animation of the interaction history for a sketch is not necessarily the optimal presentation method. Complex animations can be difficult to perceive accurately (Dragicevic et al., 2011) and are also potentially time-consuming to view in their entirety. For that reason, we propose two new *static* techniques for automatically summarizing sketch history captured during one or several design sessions: a *comic strip* of representative frames (or highlights) during the history, and a *summary frame* that annotates the changes made to the sketch in a single image. Both approaches rely on a bottom-up agglomerative clustering algorithm (Jain et al., 1999) that combines adjacent frames (each representing a stroke) into *frame aggregates* while retaining the causal sequence of the interaction history. The decision of which frames to combine depends on the distance between consecutive frames as computed

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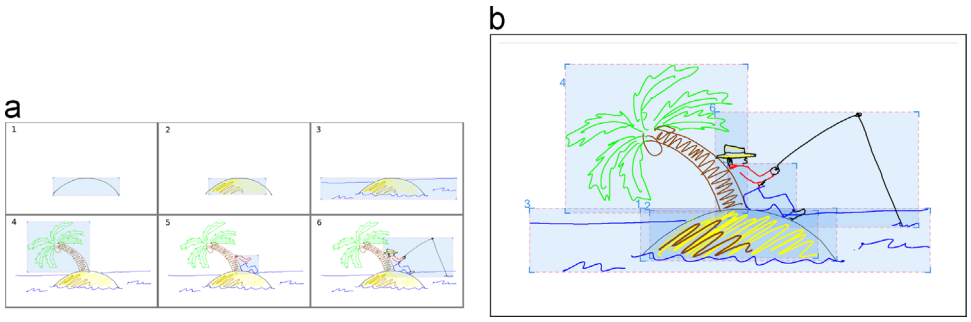

Fig. 1. Our two Sketcholution visual history mechanisms illustrating the evolution of a sketch. (a) Comic strip (6 frames), (b) summary frame (events 1–6).

by a *frame distance function*. The resulting aggregation dendrogram can be cut at any level to yield a desired number of frames (for comic strips), or a particular distance threshold between events (for summary frames).

To determine which history presentation—animation, comic strip, or summary frame—is most efficient, we conducted a user study comparing the completion time of participants recovering the causal sequence of visual components in a sketch. Results show that both comic strip and summary are significantly faster than animation. These results also provide compelling evidence to the controversy surrounding animation for comprehension (Tversky et al., 2002).

2. Related work

Our sketch captury and summary mechanism lies at the intersection of sketching, early design, and interaction histories. Below we review relevant work in these research areas.

2.1. Sketching and cognition

A *sketch* is a rapidly created freehand drawing that is not intended to create finished work, but rather to visually explore ideas (Ullman et al., 1990; McKim, 1972). Sketches can be used in the design of electrical, mechanical, scientific, mathematical, and software artifacts (Sutherland, 1964). For this reason, sketches are often used for idea generation and recording in early design—see below.

The order in which we sketch and draw reflects how we think. Taylor and Tversky (1992) studied how people create regional maps and observed that the order in which people draw reflects their mental organization of the space. Regions which had features at multiple scales were depicted starting with larger features first followed by smaller ones. Sketches themselves have a definite structure similar to language and consists of basic elements such as lines and blobs (Tversky et al., 2000). Tversky (1999) showed that the order of sketching elements reveals the designer's underlying conceptual organization.

2.2. Sketching for early design

Design is a gradual, iterative process, often beginning from ill-defined or difficult problems that are decomposed, explored, and integrated in turn to yield many possible solutions (Taborda et al., 2012). Sketches play an important role in externalizing ideas during early design (McKim, 1972), providing a "visible graphic memory" (p. 127) that facilitates creativity by providing an easily accessible database of generated ideas and by stimulating building on earlier ideas. Studies show that pictorial representations in general, and sketching in particular, are more effective than any other representations during early phases of ideation and creativity (Mckoy et al., 2001). Furthermore, pen and paper remain the most common tools for sketching in early design (Ullman et al., 1990). Greenberg et al. (2011) present a collection of methods to illustrate how to design with sketching.

Nevertheless, with the recent proliferation of pen-input devices, many efforts have been made to develop sketch-based interfaces for early design in a wide variety of domains such as architecture (Dorsey et al., 2007), automotive design (Kara and Shimada, 2008), and software design (Chen et al., 2003). These approaches all aim at replicating the good properties of paper—such as minimal learning curve, natural and precise interaction, and physical affordances—while retaining the unique benefits afforded by digital media, such as replication and composition of sketches.

2.3. Interaction logs and graphical histories

Interaction logs and histories are common in human–computer interaction due to their relation to undo and redo operations, and modern user applications typically support multi-level versions of these, sometimes of a selective nature (Berlage, 1994). Similarly, navigation histories are central to web browsers, allowing users to easily go back and forward while browsing the Web. Heer et al. (2008) carefully review the design space of interaction histories; we refer to their survey for further details on interaction capture and recall. Compared to Heer et al., our work targets a different media type and uses an aggregation algorithm to chunk the history.

Interaction data can be used to even greater effect. *Graphical histories* do not just maintain a list or stack of interactions, but also show them using a graphical summary (Kurlander and Feiner, 1988). This is most commonly done using a thumbnail image of previous state (Heer et al., 2008; Ma, 1999), and allows for capturing interactions over time (Nancel and Cockburn, 2014). In recent work, Heer et al. (2008) propose a comic strip-style graphical history using thumbnails of previous visualizations. Further, recent work has shown that augmenting sketch histories with contextual information such as pictures audio and videos improves the effectiveness of sketching for communication in early design (Li et al., 2012). Proper segmentation with users' guidance makes the graphical history easier to understand (Noris et al., 2012).

Beyond interaction data, histories have also been used for summarizing other media types. For example, histories for binary image files can be modeled using a directed acyclic graph to store temporal and semantic relationships (Chen et al., 2011). For video histories, Barnes et al. (2010) proposed continuous zooming to support navigation in time. Building on this, Ajmal et al. (2012) give a comprehensive introduction to video summarization techniques, of which cluster-based and color-based methods are partially similar to our proposed aggregation approach. Eccles et al. (2008) integrated geotemporal information into storytelling and presented stories with data such as behaviors and events. However, compared to all of the above techniques, our aggregation