TimeSets: Timeline Visualization for Sensemaking

Phong H. Nguyen, Kai Xu, Rick Walker, and B.L. William Wong

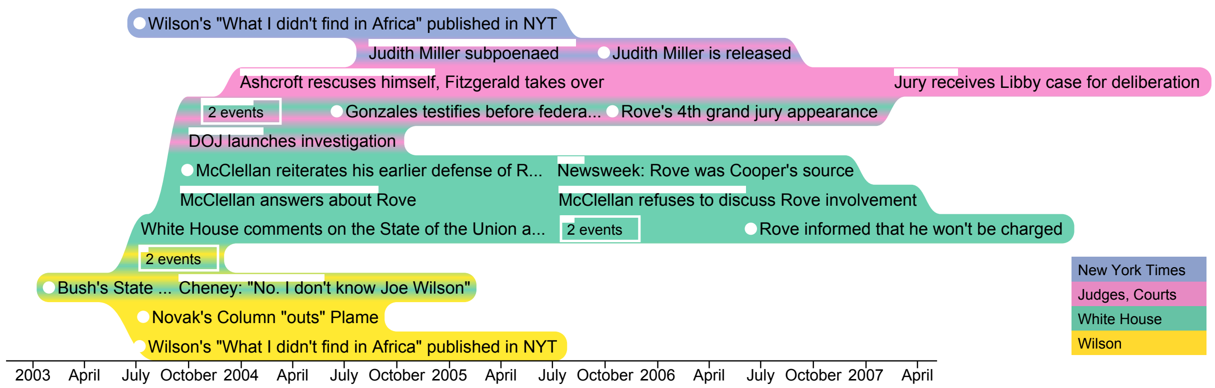

Figure 1: TimeSets visualization of the CIA leak case, in which the identity of CIA operative Valerie Plame was made public [9]. The timeline contains events happened from 2002 to 2007, each has a time stamp or interval, a label, and one or two topics such as "White House". Events are positioned along the horizontal time axis based on timestamps, and vertically grouped by topics. Time point events are shown with a white circle to its left, and the interval events with a horizontal bar on top showing its time span. Each topic has a unique color (see the legend in the bottom right corner), and events shared by two topics have gradient backgrounds, transitioning between the colors of the two topics. The level of details of each event is adjusted dynamically based on the amount of information and available display space, resulting in three levels: full label, trimmed label (ending with "..."), and aggregated events (such as "2 events").

Keywords: sensemaking, provenance, timeline, set visualization

1 Introduction

A timeline is a sequence of events and is typically visualized by plotting them along a time axis at the instant at or interval over which they occur [10]. Timelines are applied in many domains such as medical records [10] or music [2]. Events in a timeline are commonly categorized into topics or *sets*. For example, academic publications usually belong to one or more disciplines; similarly, news articles fall into different categories such as politics and sports.

Timeline visualizations typically use icons to indicate time-point events and horizontal bars for interval ones [10]. These are usually accompanied by a short line of text describing the event. To show set relations, existing methods either color-code the icons or use different shapes [7]. The layout algorithm of these methods usually focuses on avoiding event text overlap only [7]. As a result, events in the same set are not always placed close to each other. This makes it difficult to follow them chronologically or observe an overview of the distribution of events in a set. Another approach is to apply general set visualization techniques to fixed-position events of the timeline. For example, Bubble Sets [3] draws a curved boundary surrounding same-set elements, while LineSets [1] uses a Bézier curve passing through all of them. However, directly applying these methods may introduce extra edges and crossings, which hampers the readability of the timeline.

In this paper, we propose a novel timeline visualization, *TimeSets*, that facilitates making sense of set relations among events in the timeline. It provides an overview of set distribution, helps identify the trend of a set, and makes it possible to compare sets over time. Its design follows two Gestalt principles of grouping – *proximity* and *uniform connectedness* [6]. TimeSets places related events close together, and colors the set background to connect its events visually. More specifically, TimeSets:

- clearly shows the events within a set over time and their relationships with other sets;
- dynamically adjusts the level of details of each event to suit the amount of information and display estate;
- uses colored gradient backgrounds for events belong to multiple sets and curved set outlines to emphasize its grouping.

We are also investigating on applying TimeSets on visualizing notes taken by users during their data analyses. Such provenance information may help users recall their findings and support their sensemaking process.

2 Related Work

The most common form of timeline visualization uses a horizontal axis to represent time progressing from left to right, with events positioned horizontally according to their timestamps. A well known example is the LifeLines [10] – a visualization of personal medical records. LifeLines uses icons to indicate discrete events and thick horizontal lines for continuous ones. Techniques such as aggregation [5] and interaction [2] are commonly used when there are a large number of events to save display estate.

There has been considerable work on set relationship visualization, which commonly uses closed contours as in Venn or Euler diagrams. Texture and color can be used to depict more complex set relations [11]. However, these cannot be applied to the set relationships in timelines because the event position along the time axis is fixed. Recently there have been a number of papers on visualizing the set relationships of data items with fixed locations. To connect same-set elements, Bubble Sets [3] draws an iso-contour surrounding them, and LineSets [1] uses a Bézier curve passing through all the elements. KelpFusion employs both lines and areas to connect elements, and has been shown to have a significant advantage in readability tasks when compared to Bubble Sets and LineSets [8]. However, directly applying the KelpFusion method to timeline set visualization will introduce extra line segments and edge-text crossings that may reduce readability.

3 Method

Event Visual Representation In TimeSets, an event is visualized as a line of text, showing its *label*. The visual indicator of event time is a circle (for a time-point event), or a horizontal bar (for an interval event). The *time circle* is shown to the left of the label, while the *time bar* is shown above the label. The time bar is semi-transparent for overlapping interval events, so the intersection part is visually different. To accommodate a large number of events, labels have three possible levels of detail:

Complete the event label is shown in full.

Trimmed only the first few words are shown, followed by three dots at the end.

Aggregated a few events are aggregated into a new one with its label indicating the number of events, such as "2 events".

For an aggregated event, its text border is colored to make it visually different from complete or trimmed events. Its time bar covers the span from the beginning of the earliest event to the end of the latest event within the aggregation. Figure 2 shows examples of a time-point, an interval, an aggregated event, and two overlapping interval events.

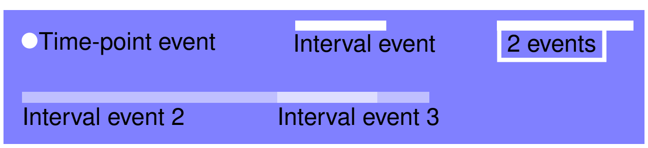

Figure 2: Visual representation of time-point, interval, aggregated events, and overlapping interval events.

Layout The layout algorithm determines the position of sets and the events within them. It consists of four steps. First, the vertical ordering of sets is computed to ensure that two sets that share events are next to each other wherever possible. Then, sets are further divided into layers, and events are assigned to their layers. During this step, an event is duplicated if it is shared by non-neighboring sets. After that, the position and length of each event is dynamically adjusted to fit into the display space. Finally, layers are compacted to remove any gaps between them, before layer sizes are adjusted to allow for a consistent level of detail across the sets.

Set Visualization Each set is filled with a color selected from the Qualitative Set 2 of ColorBrewer [4] to make them easily distinguishable. Coloring the entire set area visually connects the events within. The area size is not exactly proportional to the number of events, but may be used as a rough estimate. The intersection between sets is represented as a linear color gradient – changing between the two set colors. While the color gradient provides a smooth transition, it becomes difficult to recognize the start and end of the intersection. To address this issue, multiple color transitions are used instead of a single transition for the entire layer. For example, in Figure 3, the color transition between green and yellow is repeated multiple times so that both colors are clearly shown in every row of the intersection, and there is no significant difference in color perception among these rows.

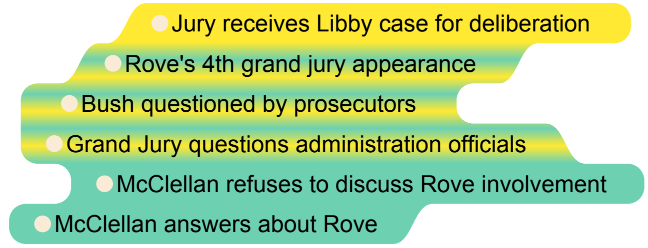

Figure 3: Color gradient technique to encode set memberships. The gradient colored part shows three shared events between two sets.

4 Application of TimeSets to Visualize Provenance Information

While exploring data, users may take notes to record their findings. Visualizing this provenance information in the temporal order may help users recall their sensemaking process. The temporal aspect can reflect when notes are taken or when the event mentioned in the note happens. Text analysis techniques can be applied to extract entities or keywords in notes, which are considered as sets in the TimeSets visualization.

The demonstration of TimeSets can be found at `http://www.invisque.com/timesets/demo.mp4`.

References

[1] B. Alper, N. H. Riche, G. Ramos, and M. Czerwinski. Design study of LineSets, a novel set visualization technique. *IEEE Transactions on Visualization and Computer Graphics*, 17(12):2259–67, Dec. 2011.

[2] P. André, M. L. Wilson, A. Russell, D. A. Smith, A. Owens, and M. Schraefel. Continuum: designing timelines for hierarchies, relationships and scale. In *ACM Symposium on User Interface Software and Technology*, pages 101–110, New York, New York, USA, Oct. 2007. ACM Press.

[3] C. Collins, G. Penn, and S. Carpendale. Bubble sets: revealing set relations with isocontours over existing visualizations. *IEEE Transactions on Visualization and Computer Graphics*, 15(6):1009–16, 2009.

[4] M. Harrower and C. a. Brewer. ColorBrewer.org: An Online Tool for Selecting Colour Schemes for Maps. *The Cartographic Journal*, 40(1):27–37, June 2003.

[5] S. Havre, E. Hetzler, P. Whitney, and L. Nowell. ThemeRiver: visualizing thematic changes in large document collections. *IEEE Transactions on Visualization and Computer Graphics*, 8(1):9–20, 2002.

[6] K. K. *Principles of Gestalt psychology*. Oxford, England: Harcourt, Brace, 1935.

[7] M. LLC. TimeGlider. `http://timeglider.com/`, 2012.

[8] W. Meulemans, N. H. Riche, B. Speckmann, B. Alper, and T. Dwyer. KelpFusion: A Hybrid Set Visualization Technique. *IEEE Transactions on Visualization and Computer Graphics*, 19(11):1846–58, Nov. 2013.

[9] npr. Timeline: The CIA Leak Case. `http://www.npr.org/templates/story/story.php?storyId=4764919`, 2007.

[10] C. Plaisant, R. Mushlin, A. Snyder, J. Li, D. Heller, and B. Shneiderman. LifeLines: using visualization to enhance navigation and analysis of patient records. *Proceedings of the AMIA Symposium*, 08(98):76–80, 1998.

[11] C. Ware. *Information Visualization: Perception for Design*. Elsevier, 2013.