SEQIT: Visualizing Sequences of Interest in Eye Tracking Data

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ABSTRACT

Eye tracking is becoming widely used in HCI and many other fields to study user behaviour. Eye tracking data explains user attention patterns in great detail, but analysis is a challenge because of its volume and complexity. Various visualizations have been designed to aid such data analysis, but none of them focuses on the sequential patterns in eye gaze, which can reveal insights in user behaviours. We present the SEQIT visualization system designed for sequence analysis of eye tracking data. Using pre-defined areas of interest (AOI), SEQIT aggregates fixations into AOI visits and presents sequences of AOI visits in a timeline view. It supports comparisons between multiple sequences and exploration of sequence patterns associated with user characteristics.

Keywords: eye tracking, aggregation, linked views, time series

Index Terms: I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction techniques

1 INTRODUCTION

We present SEQIT, a visualization system that facilitates interactive discovery and analysis of sequences of interest (hence SEQIT) in eye tracking data. The system focuses on finding sequence patterns that correlate with certain user characteristics in the dataset.

Eye tracking data consists of fixations and saccades. Each fixation occurs in a short period of time and at a spatial location. Two consecutive fixations are linked by a saccade, which is a rapid movement of the eye. In interface analysis, meaningful regions in the visual stimulus are often defined as areas of interest (AOI) to provide the semantics of the fixation locations. In SEQIT, both the spatial and temporal attributes of the fixations are presented, and the aggregation of fixations into AOI visits is used.

The example dataset we show here is from an experiment conducted with eye tracking [2]. There are 62 participants in the study, each performed 80 tasks. User characteristic data recorded include three cognitive ability measures: perceptual speed, verbal working memory, and visual working memory. Each measure is a quantitative value computed from the respective cognitive test.

While an increasing number of eye-tracking visualizations have been developed in recent years, a recent survey found that many of the systems lack support for interactive analysis [1]. In their classification, SEQIT is both point- and AOI-based and facilitates interactive spatial-temporal analysis with multiple comparisons; there is no previous system that falls into this set of categories.

2 SEQIT DESIGN

SEQIT uses aggregation and linked multiform views among other visualization idioms. The eye tracking data is presented in multiform views: individual fixations are shown in details only on demand, and for overview, we choose to reduce the complexity by aggregating the fixations. The views in the interface are connected by linked highlighting and shared colour encoding, and we use interactivity to support exploration and discovery of sequence patterns.

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2.1 AOI Visits

AOI visits are derived from the aggregation of fixations. Successive fixations within the same AOI are grouped as an AOI visit. The duration of the AOI visit is the summed durations of individual fixations in the AOI visit. Each AOI is assigned a colour to be applied consistently throughout the interface for representing the AOI.

2.2 Interface Panels

SEQIT, as shown in Figure 1, consists of four closely connected panels: review, timeline, user characteristics, and sequence tool.

2.2.1 Review Panel

The review panel has the visual stimulus as the background and overlays additional data. The visual stimulus in the example dataset is a grouped bar chart that was shown to the experiment participants. Data that can be displayed on top of the visual stimulus include the individual fixations and saccades, a heatmap of the fixations, and the AOI regions. The visual stimulus in the background provides the spatial context for the overlaid data for easy reference.

2.2.2 Timeline Panel

The timeline panel presents the eye-tracking data in the form of AOI visit sequences. The gaze sequences of participants performing the same task are displayed as rows in this panel. Each sequence is visually encoded in a series of horizontally stacked bars to represent the AOI visits, with the length of each bar denoting the duration of that AOI visit, and its colour corresponding to the AOI of the visit. For comparing the behaviour of multiple users completing the same task, all of the rows of AOI visit sequences in the panel are aligned on the left at the trial start time. Similar designs have been used in ISeeCube [3] and EyeC [4].

There are two time scales at which the timeline can be presented: absolute and relative. With the absolute time scale, the actual times of the trials are mapped consistently across all rows, so that the total length of the bars represents the total duration of the trial. With the relative time scale, the proportion of trial completed acts as the time scale, under which all bars are of the same length and aligned at the rightmost point, which denotes 100% of trial completed.

2.2.3 User Characteristics Panel

The user characteristics panel presents the cognitive ability measures of the participants. Each measure forms a bar chart, aligned with the timeline by participant. The bar chart of each measure can be sorted, and the rows in the timeline is re-ordered accordingly at the same time. Sorting makes it easy to find correlations between user characteristics as well as between any user characteristic and sequence patterns in the timeline.

2.2.4 Sequence Tool Panel

Using the sequence tool, users can create short sequence patterns and visualize their occurrences on the timeline. Clicking the "New sequence" button enters edit mode, where users can select the AOIs in the review panel to form a sequence pattern (Figure 2). Created sequences are saved in a list in this panel.

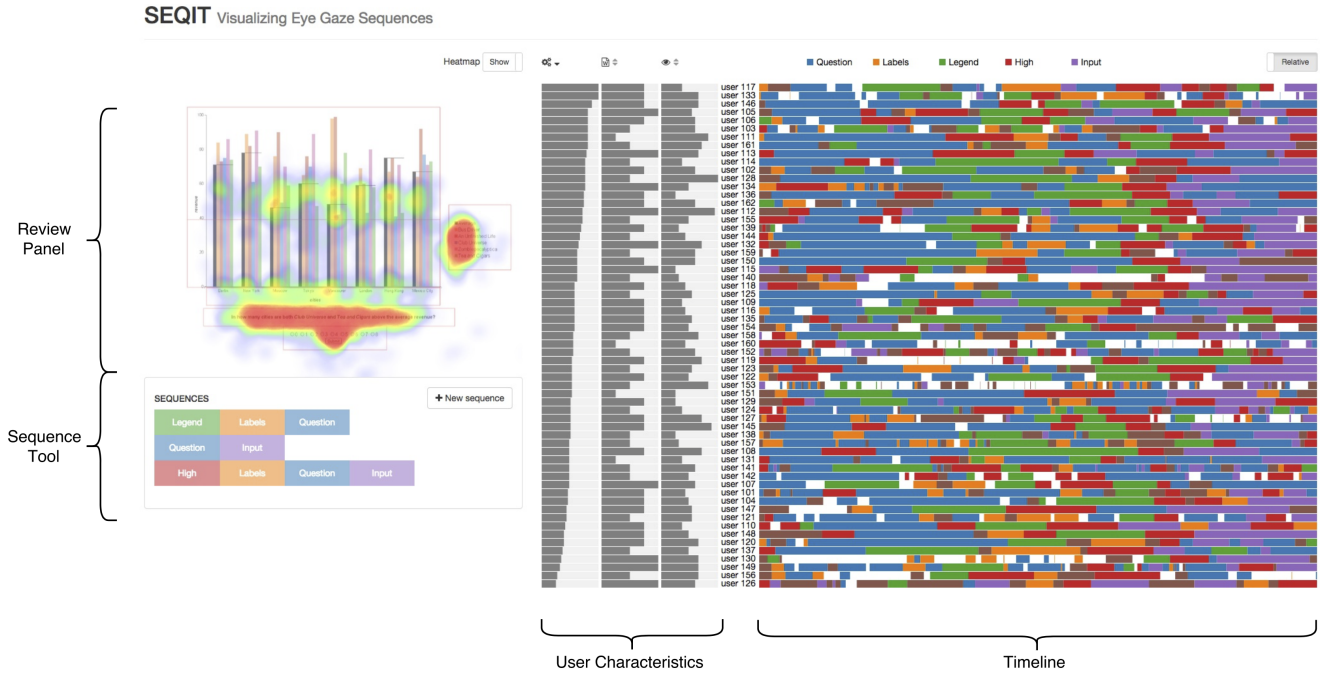

Figure 1: SEQIT, with heatmap toggled on and timeline in relative scale while sorted by perceptual speed. The review panel is in the top-left corner, below which is the sequence tool, and to their right are the user characteristics panel and the timeline panel.

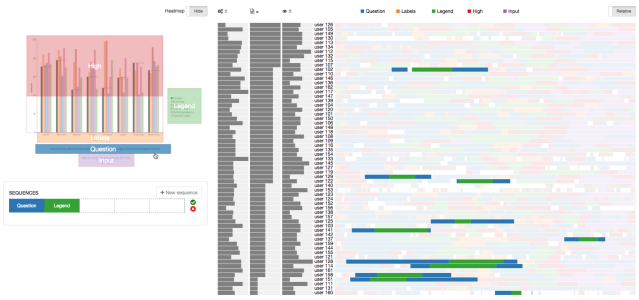

Figure 2: The sequence pattern Question-Legend-Question is highlighted during the sequence pattern creation process. Note the more frequent occurrence in the lower half of the timeline that is associated with participants with low verbal working memory capacity.

2.3 Interface Interactions

The four panels are connected through linked highlighting. When users hover over the region of an AOI in the review panel, the region itself is highlighted and labeled, and in the timeline, every bar that represents a visit to this AOI is also highlighted. In the sequence tool, hovering over a saved sequence pattern highlights its occurrences in the timeline.

When users hover over a row in the timeline, a fisheye distortion is applied to zoom into this particular row, the colours of other rows are faded out to further highlight the selected row, and the fixations and saccades from the selected trial are drawn in the review panel over the visual stimulus.

3 Discussion and Future Work

To handle the exploration and analysis of large volumes of data, SEQIT follows the "overview first, then details-on-demand" mantra [5] and uses focus+context idioms. SEQIT presents the eye tracking data at the fixation level as well as the aggregated AOI-visit level. The system supports tasks in different stages of the analysis workflow, while giving the freedom of controls to various parameters.

One limitation is that SEQIT currently supports analyzing users on one task at a time, whereas comparing trends across multiple tasks could provide greater insight. Another improvement would be to encode more detailed information, such as individual fixation duration, into the timeline rows to take better advantage of the fisheye zooming; it does not provide much value in the current version.

SEQIT is available at `http://mikewu.net/SEQIT` and open sourced at `https://github.com/m-wu/SEQIT`.

4 Conclusions

The SEQIT visualization system for sequence analysis of eye tracking data supports tasks at various stages of the data analysis: the timeline gives an overview of the AOI visits, the sequence tool supports defining and visualizing specific sequence patterns, and the review panel shows the fixations and saccades of the selected trial. The fast and responsive interface features a clean design and is easy to use to discover sequences of interest.

References

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