Sense.me – Open Source Framework for the Exploration and Visualization of Eye Tracking Data

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Abstract

We present a new open-source prototype framework to explore and visualize eye-tracking experiments data. Firstly, standard eye-trackers are used to record raw eye gaze data-points on user experiments. Secondly, the analyst can configure gaze analysis parameters, such as, the definition of areas of interest, multiple thresholds or the labeling of special areas, and we upload the data to a search server. Thirdly, a faceted web interface for exploring and visualizing the users' eye gaze on a large number of areas of interest is available. Our framework integrates several common visualizations and it also includes new combined representations like an eye analysis overview and a clustered matrix that shows the attention time strength between multiple areas of interest. The framework can be readily used for the exploration of eye tracking experiments data. We make available the source code of our prototype framework for eye-tracking data analysis.

Index Terms: H.5.2 [Information Interfaces and Presentation]: User Interfaces—Graphical user interfaces (GUI); K.8.1 [Personal Computing]: Application Packages—Freeware/shareware;

1 Introduction

Eye-tracking data analysis is an important and challenging task, with application in many fields of research. It is used for the analysis of human-computer interaction processes, and to augment user interaction [1]. Multiple and complex eye-tracking datasets are a normal result of user experiments. Therefore, there is the need to develop tools to help understand hidden eye-movement patterns. These should support the definition and exploration of a large number of areas of interest (AOIs). Earlier work in this field serves as an inspiration to us [2] [7]. Eye-tracking data analysis uses different methods [3] and visualization techniques [2]. We base this work on both Point-based and AOI-based approaches. These are two common approaches used, however, there are only a few examples of systems using these two approaches together [2]. Our prototype allows the analysts to explore infrequent patterns by allowing a clear look at the number of possible values on each data facets, with clustered results in terms of fixation time and fixation count and distinctive visual elements. It makes available data filters and allows the narrowing down of results. It provides data configuration and annotation, together with standard and also new visualizations.

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2 Sense.me Framework Approach

As shown in the framework diagram in Figure 1, our approach starts by allowing the upload of raw eye-tracking datasets (from standard eye-trackers) into a dedicated search server (i.e., Elasticsearch). One can use the configurator to specify settings on the dataset on every new raw dataset upload. These settings are useful to define areas of interest, upload images for each AOI, create categories of AOIs, configure multiple thresholds and annotate the data (e.g., AOI isAnswer, the grouping of fixation times into 10 bins, etc.). This allows the analysts to do filtering on a high number of eye-tracking data points and AOIs. Typically, on our experiments, 40 areas of interest are the minimum needed. It also allows the analyst to group, label and aggregate data points on each AOI according to specific analysis needs. The filter settings are accessible using a standard Elasticsearch server and a new customizable web interface that we developed for the specific purpose of eye-tracking data exploration. A number of visualizations, linked to the search queries, are available. This capability is useful for filtering data on the different facets and on the respective facets' values, while still keeping all the visualizations synchronized with the filters. We expect to give a better exploration experience of the different anomalies on the eye-tracking datasets to the analysts. These details are described in the next section.

3 Implemented Visualizations

Our goal is to improve the exploration by providing search and filter capabilities (e.g., on specific text fields, settings), data aggregations (e.g., time thresholds or statistics calculations, groups of experiments, trials, and users). These capabilities are part of the data visualizations (Table 1) that we are implementing in the prototype. We implemented visualizations that are familiar to the analysts, such as, dendrograms (aggregations of attention time spent on each AOI), Sankey diagrams (to show which AOIs received more attention by different users). We are also implementing a time cube visualization [4] (to allow the aggregation and visualization in time of the different AOIs, in terms of attention time, or fixation counts). These visualizations are supported by the Elasticsearch back-end and by the faceted web interface, allowing the narrowing down of interesting, normal or abnormal eye trajectories. Moreover, additional visualizations are available in the prototype. They also help on the filtering and clustering of the data. We implemented a parallel coordinates diagram (with filtering of multiple data parameters), a new arc diagram where each endpoint links to a visual depiction of each AOI (it includes a scan-path representation and a heat map of eye data-points distribution for each AOI image).

4 Use Case and Initial Results

Figure 2 (A) shows findings from an eye-tracking experiment. Users performed a visual exploration of 43 AOIs (scatter-plots images) taken from the scatter-plot exploration system presented in [5] and had to search for identical images, in comparison to a reference image. They acknowledged when those images were found,

Table 1: Overview of Main Visualizations (details on Section 3)

Visualization	Implemented
Dendrogram (fixation aggregation)	Yes
Parallel Coordinates	Yes
Sankey	Yes
Arc Diagram + AOIs + Heatmap	Yes
Clustered AOIs + AOI scanpath	Yes
Dateline (time based AOIs scanpath)	In Progress
Time Cube	In Progress
Timelines with AOI duration	In Progress

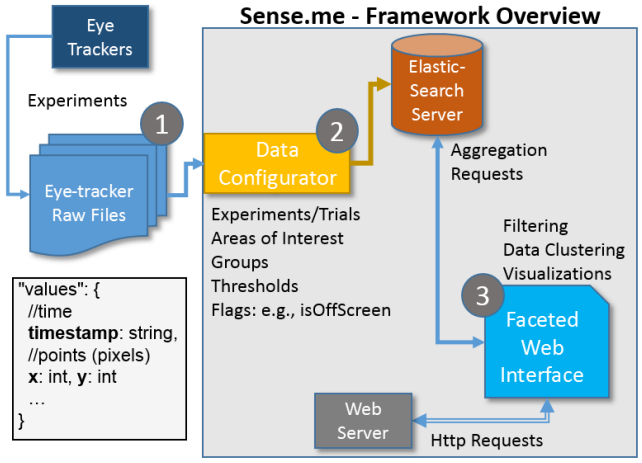

Figure 1: Framework Overview. Firstly: Record eye-tracking data (from experiments) on multiple files (1). Secondly: Specify settings using the Data Configurator, and upload the files to the search server (2). Finally: Use a faceted web interface (3) to explore and visualize the users' eye patterns. We make available the source code for this framework on GitHub [6].

by pressing a keyboard key. We annotated the dataset beforehand to know which answers were correct (label: AOI isAnswer). We explored eye movement patterns in the eye-tracking dataset that correspond to the correct AOIs (isComparison and isAnswer AOIs labels). Figure 2 (A) also shows eye movements between only two AOIs. The blue arcs intensity represent the quantity of eye jumps between two AOIs (darker color means more jumps). More time spent on each AOI leads to larger blue circles. Hovering the mouse on a circle (AOI) highlights the respective AOI image on the list of images of the arc diagram. We can activate an overlaid heat map on top of the images (AOIs) to better visualize the gaze points distribution on each AOI. Figure 2 (B) shows a parallel coordinates diagram, each color represents a different user. We can filter eye data points of each trial where several users looked at the reference image (defined as isComparison using the data configurator). We explored the different fixation time on specific AOIs. Figure 2 (C) shows all AOIs clustered by fixation time and count. To represent levels for the number of jumps between AOIs, we use arrows (we call it traces) colored from dark to light gray. Using the filtering and aggregation, together with the multiple data visualizations, we could identify interesting eye movement patterns. As an example, we investigated scatter-plots that were more difficult to interpret by the user (i.e., they required intensive comparisons with a reference image).

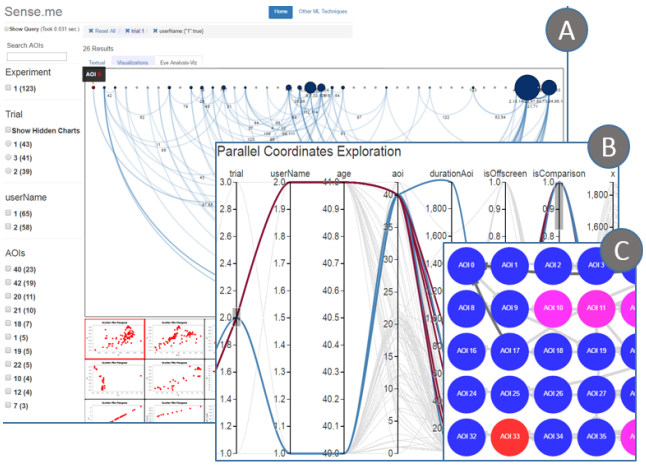

Figure 2: Visualization Examples: A new arc diagram combined with AOIs matrix (A). A parallel coordinates diagram linked to filters (B). Clustered AOIs, according to fixation time and count. Scan-paths are also visible (C).

5 Conclusion and Future Work

We presented a new open source framework that allows the exploration of eye-tracker raw data. We propose the usage of several well-known visualization techniques, together with other combinations of standard visualizations to help experts and non-experts to easily explore eye-movement tracking datasets generated from experiments. We are integrating into one framework multiple visualization types (e.g., temporal, spatial-temporal, multiple users, interactive). Our framework makes usage of a search server and it relies on both well-known point-based and AOIs-based approaches for eye-tracking analysis and exploration. We will work on the analysis of other stimuli, such as dynamic stimuli or 3D stimuli, and include more advanced filtering and statistics into this framework.

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