Demo of the EyeSAC System for Visual Synchronization, Cleaning, and Annotation of Eye Movement Data

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ABSTRACT

Eye movement data analysis plays an important role in examining human cognitive processes and perceptions. Such analysis at times needs data recording from additional sources too during experiments. In this paper, we study a pair programming based collaboration using two eye trackers, stimulus recording, and an external camera recording. To analyze the collected data, we introduce the EyeSAC system that synchronizes the data from different sources and that removes the noisy and missing gazes from eye tracking data with the help of visual feedback from the external recording. The synchronized and cleaned data is further annotated using our system and then exported for further analysis.

CCS CONCEPTS

• **Human-centered computing** → *Visualization design and evaluation methods*; *Visual analytics*; *Visualization techniques.*

KEYWORDS

Annotation, eye tracking, visualization, filtering, synchronization, denoising

ACM Reference Format:

Ayush Kumar, Debesh Mohanty, Kuno Kurzhals, Fabian Beck, Daniel Weiskopf, and Klaus Mueller. 2020. Demo of the EyeSAC System for Visual Synchronization, Cleaning, and Annotation of Eye Movement Data. In *Symposium on Eye Tracking Research and Applications (ETRA '20 Adjunct), June 2–5, 2020, Stuttgart, Germany*. ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3379157.3391988

1 INTRODUCTION

There is advancement in the application of eye tracking as a window to cognitive processes such as those relevant in human-computer interaction, visual perception, or reading [Duchowski 2002; Holmqvist et al. 2011]. Valuable information related to cognitive processes is acquired through visual analysis of eye movement data [Blascheck et al. 2016; Kumar et al. 2018b; Kurzhals et al. 2014]. In traditional settings, eye movement data along with stimuli information is used for analysis. However, in quest for better understanding of cognitive processes [Duchowski 2002], eye tracking researchers do not rely only on eye movement data but also back their assessment through external audio/visual feedback and stimuli recordings [Jermann et al. 2010; Kumar et al. 2018a; Nüssli 2011; Pfeiffer et al. 2013]. The need to work with data from multiple sources led us to design a multi-functional system that could help eye tracking researchers to synchronize the data offline after the experiment is completed. Furthermore, data loss due to frame dropping, poor calibrations, or missing gazes remains an issue despite technological advancements in eye tracking [Nyström et al. 2013]. To address this issue, we added denoising functionality in our system that lets users correct missing gazes or noisy frames. To assist better analysis of eye movement data, we facilitate video-based annotation of the data. Our tool lets users annotate cleansed and synchronized data frame by frame, which is then exported for further analysis.

ETRA '20 Adjunct, June 2–5, 2020, Stuttgart, Germany

ACM ISBN 978-1-4503-7135-3/20/06.
https://doi.org/10.1145/3379157.3391988

2 SYSTEM DESIGN

We illustrate EyeSAC system for an eye tracking study on pair programming based collaboration [Villamor and Rodrigo 2017] in which two participants were performing a coding task, with one being the *Driver* and the other being the *Navigator* [Nawrocki and Wojciechowski 2001; Williams and Kessler 2002]. Using Pupil Labs glasses [Kassner et al. 2014], we recorded eye movement data for both participants using their head camera video mounted to their eye trackers. An additional external video camera was used to record the full lab space in order to assess the participants' behavior.

2.1 Timeline Visualization

The temporal aspect of the eye movement data is visualized in three levels as a Lasagna plot [Swihart et al. 2010], where the horizontal axis represents a timeline and the frames associated to it (Figure 1(g)). The vertical axis is separated into three levels, where the topmost level visualizes the gaze distance between both participants projected on to the screen to understand the gaze coupling [Richardson and Dale 2005]. Gaze distance is color-coded with a sequential red color, where a darker shade encodes points farther from each other and a lighter shade encodes points closer to each other. In case of missing gaze information due to missing frames, calibration error, or off-surface gaze, the distance is shown by blue color. The bottom two levels of the timeline in Figure 1(g) display the individual gaze information for each participant. If the gaze is on-surface, then that frame is encoded with green color, and with red color in case of off-surface. Noisy frames are represented

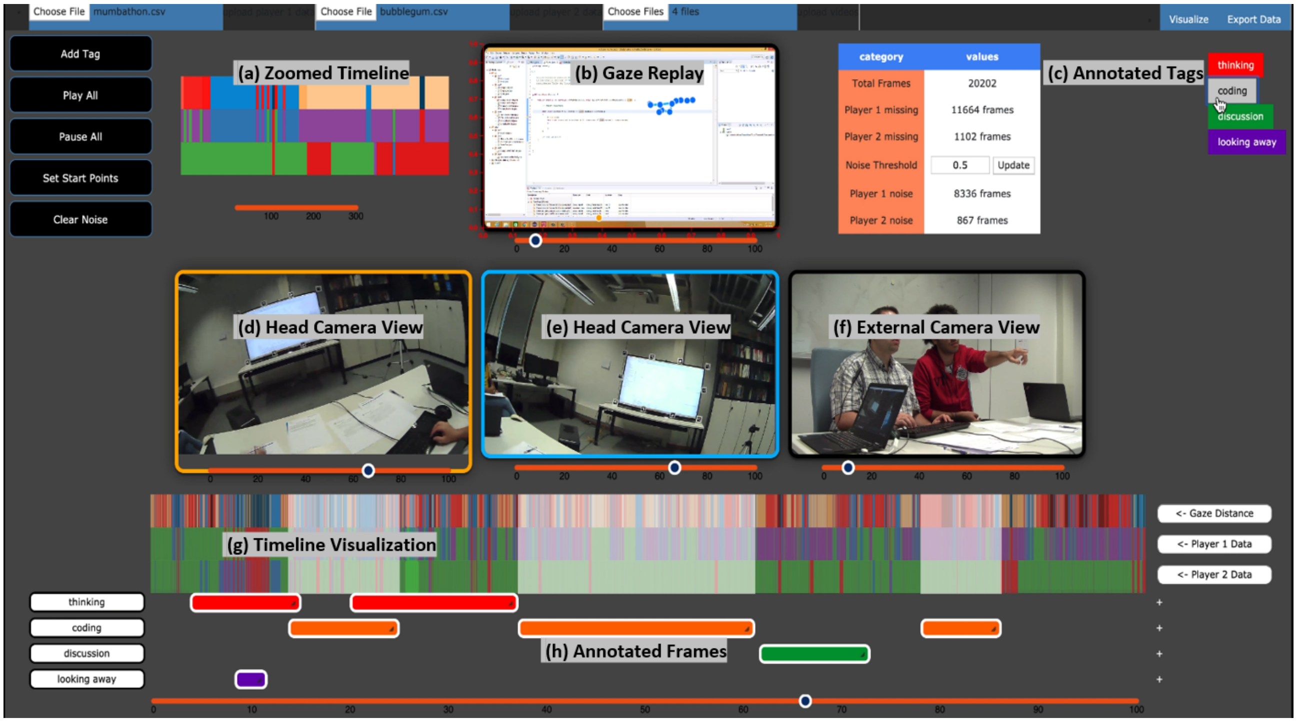

Figure 1: Screenshot from the EyeSAC system.

by purple color and missing frames by steel-blue as shown in Figure 1(g). In this example, there are many noisy frames associated with Player 1 (participant). It is due to the fact that this participant was wearing glasses which made it difficult for the eye tracker to detect the pupil of the eye. We also display a *Zoomed Time Series Plot* (Figure 1(a)) of main timeline visualization (Figure 1(g)), where a number of frames are selected using a slider below the zoomed timeline.

2.2 Video Synchronization

Since videos are recorded from different systems with varying clock cycles, we target at synchronizing all of them. All videos in EyeSAC are equipped with individual sliders below them to adjust the start of the study, as shown in Figure 1 (b, d, e, f). It uses a visual and audio cue from the stimulus (Figure 1(b)) to find the start of the study and set with a button in the menu named *Set Start Points*. These synchronized videos are then used further for removing noise and adding annotations.

2.3 Noise Removal

Our EyeSAC system addresses noise removal due to missing frames, varying confidence level (ranges 0 to 1), and error-prone calibrations. For now, we are using automatic noise removal by averaging the previous two gaze locations and the following two gaze locations in place of the noisy frame. In case of gaze being off-surface on a frame, we check the confidence level associated. If the confidence level is less than a noise threshold, we label it as noisy and use the above mentioned averaging technique for noise removal.

2.4 Annotation

There are annotation or labeling tools for different kinds of study analysis [Wittenburg et al. 2006]. EyeSAC facilitates video-based annotation of the study data. It lets analysts annotate time ranges of data, while looking into the associated gazes and videos simultaneously. We select frames using multiple annotated sliders as shown in Figure 1(h) and annotates them as per the category analyst suggests. We use four generic category of tags, i.e., *thinking*, *coding*, *discussion*, and *looking away* for our analysis as shown in Figure 1(h) encoded with red, orange, green, and violet color, respectively. Annotated frames can further be highlighted and revisited using the annotated tags, as shown in Figure 1(c) where frames with coding activity are highlighted. The timeline cursor at the bottom of the annotated frames is used for timeline navigation of the study from start to end. In this example, cursor is just below the annotated frames in green (Figure 1(h)), which is used for annotating the discussion mode of participants. It is evident from the external camera recording (Figure 1(f)) that participants at the moment are in discussion mode.

The processed data and the annotations can be exported for further analysis and reporting using the Export Data button at the top-right corner of the system.

ACKNOWLEDGMENTS

Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – Project-ID 251654672 – TRR 161 (Project B01), SUNY Korea's ICTCCP (IITP-2020-2011-1-00783) supervised by the IITP and NSF grant IIS 1527200.

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