Analyzing Unconstrained Reading Patterns of Digital Documents Using Eye Tracking

Bhanuka Mahanama, Gavindya Jayawardena, and Sampath Jayarathna
Department of Computer Science, Old Dominion University, Norfolk, VA, USA
{bhanuka, gavindya, sampath}@cs.odu.edu

***Abstract*—Researchers read scientific literature to keep current in the field and find state-of-the-art solutions to various scientific problems. Prior work suggests that reading patterns may vary with the researcher's domain expertise and on the content of the digital document. In this work, we present a pilot study of eye-tracking measures during a reading task with the options for zooming and panning of the reading material. The main goal is to analyze unconstrained reading patterns of digital documents using eye movement fixations and dwell time on various sections of a digital document. Our results indicate that participants mostly focused on methodology and results sections, which is consistent with the prior work with constrained reading patterns.**

***Index Terms*—Eye-Tracking, Digital Documents, Reading Patterns**

I. Introduction

The pattern of reading digital documents varies from person to person. When reading digital documents one may zoom and pan into different sections during focused reading tasks. While this behavior seems stochastic, prior work [1] suggests that individuals with similar expertise in reading digital documents may exhibit common reading patterns. Jayawardena et al. [2], for instance, used eye tracking to analyze the reading patterns of novice researchers while reading scientific articles. In this study, all participants spent the longest time reading the methodology section, with a comparatively low cognitive load. Their experimental setup, however, did not allow participants to zoom or pan into the document being read. Therefore, the natural behaviour of reading a digital document has not been captured.

In this paper, we examine the reading patterns of novice readers allowing participants to read scientific literature in an unconstrained manner; i.e., with the freedom to zoom and pan into the document.

II. Methodology

For each participant, we conduct an eye movement analysis to obtain, 1) eye movement fixation count, and 2) dwell time, within various predefined areas of interest (AOI).

A. Data Collection

We recruited three doctoral students as novice researchers (1F, 2M) in the field of Computer Science. All participants were in their second or third year in the respective doctoral programs. They were aged 20–30 years, with normal or corrected-to-normal vision. We verified the vision of the participants by conducting a simple visual acuity test. Participants verbally confirmed their familiarity of reading scientific literature.

B. Reading Task

Participants were asked to read a preselected two-page, peer-reviewed publication. Simultaneously, their eye movements were recorded using a GazePoint GP3 desktop eye-tracker[1], which has a sampling frequency of 60 Hz and an angular accuracy of 0.5°– 1°. Prior to each recording, we used the nine-point calibration, and verified the accuracy of readings through visual inspection.

Next, we introduced the digital document viewing tool we used in the experiment to the participants. We explained the controls of the digital document viewing tool such as zooming and panning, using a different document than the reading material used in the experiment.

While the participants were reading the document, we captured the screen content and the gaze information. We used the index of the frame of the screen recording to aggregate the screen recording and the gaze position. Further, we used a single image containing the entire paper as the primary reference for mapping of an AOI.

C. Data Processing

We started the gaze processing by combining the gaze positions with each frame of the screen recording. Based on the features found in the main image and the content in a given frame, we matched the local features in the screen recording frame with the global features in the main image. We used Scale Invariant Feature Transform (SIFT) [3] on both images to identify key features. Based on the descriptors and the key points identified by the SIFT, we generated a list of potential matches between the features of the screen recording frame and the paper content. For the generation of matches, we used Brute-force matching with L1 norm.

Then we sorted the possible key-point matches based on the L1 distance to get the most resembling key-points between screen capture and the document. Using the two most resembling points (matches with lowest L1 distance), we mapped the gaze coordinates from the screen capture frame to the main image. For the mapping, we used linear interpolation to compute the coordinates on the main image. Through the analysis of the behavior of the gaze locations, we computed

[1] https://www.gazept.com/products/

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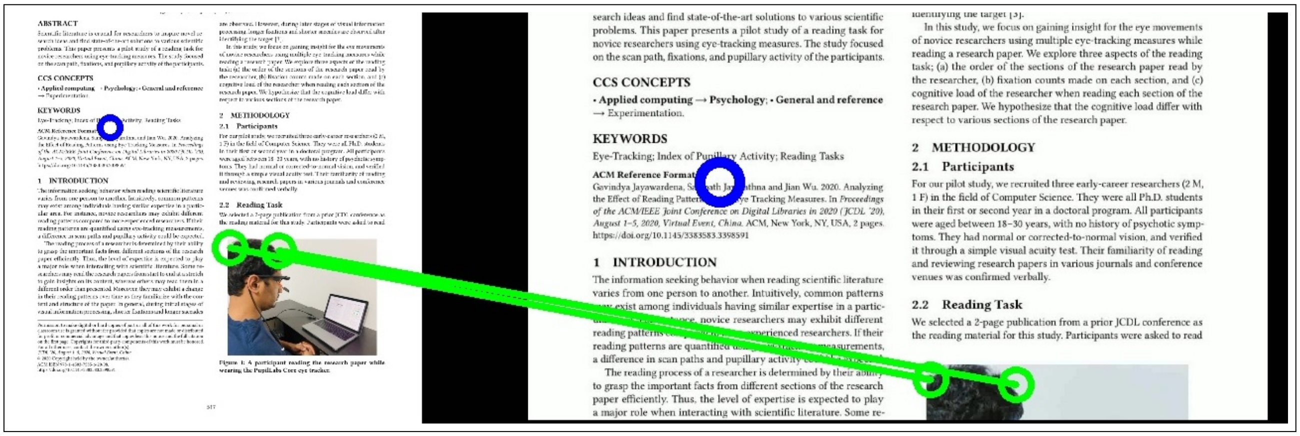

Fig. 1. Mapping between screen recording (Right) and paper content (Left). Gaze positions illustrated in blue with key-points used for interpolation in green.

two selected eye-tracking metrics; fixation count and dwell time.

D. Eye Movements Processing

For the eye movements analysis, we generated fixation count and dwell time of participants during the reading task from the eye movements recordings. Fixation count indicates the number of times that the eyes fixated on an AOI, whereas the dwell time indicates the total amount of time spent on reading or skimming an AOI.

We calculated fixations counts and dwell times of the participants using RAEMAP [4] eye movement analysis pipeline where the eye movements are classified using I-VT algorithm with a threshold of 18° [5]. We specified six AOIs: (1) title, (2) abstract, (3) introduction, (4) methodology, (5) results, (6) conclusions, and (7) references on the selected scientific article to analyze the eye-movements of participants. Then we used the fixation data and mapped them with the specific locations of the paper.

TABLE I
AVERAGE FIXATION COUNT AND DWELL TIME OF PARTICIPANTS

AOI	Fixation Count	Dwell Time (S)
Title	10.00	12.12
Abstract	9.67	12.12
Introduction	21.67	29.48
Methodology	**43.67**	**42.99**
Results	**42.33**	**44.82**
Conclusions	7.33	7.09
References	5.33	5.16

The average fixation count and dwell time (seconds) of participants on AOIs suggests that participants preferred to fixate more on both methodology and results sections. Participants spent about same amount of time reading methodology and results sections compared to the other sections (see Table I).

III. Conclusions

The primary objective of this study is to develop a methodology to capture reading patterns of novice readers in an unconstrained environment. We formulated a method to generate AOI-based eye-tracking metrics from a stream of gaze data and its corresponding screen capture. By computing eye movement measures within various sections of the document, we were able to obtain results consistent with the prior work [2] on reading pattern analysis without the option to pan and zoom. This indicates the applicability of this method for unconstrained reading scenarios.

In the future, we will focus on limiting false-positive key point matching between the on-screen content and the paper content. This is in particular useful when assessing the unconstrained reading patterns with less distinctive features such as images, charts, and tables. Further, we will incorporate additional metrics such as gaze transition and pupillometry from recorded eye-movement data.

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References

[1] J. M. Royer, M. S. Carlo, R. Dufresne, and J. Mestre, "The assessment of levels of domain expertise while reading," *Cognition and instruction*, vol. 14, no. 3, pp. 373–408, 1996.

[2] G. Jayawardena, S. Jayarathna, and J. Wu, "Analyzing the effect of reading patterns using eye tracking measures," in *Proceedings of the ACM/IEEE Joint Conference on Digital Libraries in 2020*, 2020, pp. 517–518.

[3] D. G. Lowe, "Distinctive image features from scale-invariant keypoints," *International journal of computer vision*, vol. 60, no. 2, pp. 91–110, 2004.

[4] G. Jayawardena, "Raemap: Real-time advanced eye movements analysis pipeline," in *Symposium on Eye Tracking Research and Applications 2020*. Stuttgart, Germany: ACM, 2020.

[5] D. D. Salvucci and J. H. Goldberg, "Identifying fixations and saccades in eye-tracking protocols," in *Proceedings of the 2000 symposium on Eye tracking research & applications*, 2000, pp. 71–78.