

Reading Patterns Classification Based on Gaze Data

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Abstract – Reading is a cognitive process which defines the way of acquiring knowledge. As various reading styles are used, different level of comprehension, engagement and fluency can be reached. Objective of our research is to create a prototype of a classification model to distinguish between different reading patterns from gaze fixation data using machine learning techniques. This approach can lead to a better understanding of the reading process.

Keywords – gaze; eye tracking; reading patterns; machine learning; classification;

I. INTRODUCTION

Gaze information determines what we are focusing on. Tracking of the human eye movement allows us to better understand the user behavior and visual attention, which can be more precise and reliable when compared with other techniques used to observe and describe the human intent. Nowadays, eye tracker devices are widely used as an effective tool in human-computer interaction and psychology research.

Eye tracking technology is becoming more efficient and has been widely applied to the understanding of the reading comprehension process. In order to comprehend text a person needs to be able to read quickly because a person can, generally, only keep seven pieces of information (± 2) in their short-term memory. Any additional information is quickly lost and cannot be recalled [1]. The above phenomenon results in certain disruptions in reading patterns, while whole text comprehension process is also affected. It is known that while reading, we inadvertently form rational connections between pieces of information we pick up from the text. That reflects in certain disruptions in the norms of reading paradigm and that gives us clues to our interest level in reading activities [2].

In many cases, people read just for pleasure, while their reading patterns are rather quick and leaping. When someone reads to learn while staying focused to remember new information from the text, then his eye movements tend to be slower and more stagnated. While considering mentioned reading types, is it possible to infer the reading pattern from eye movement trajectory acquired from eye tracker device? Let's suppose there is enough gaze data, can a machine learning method be used to discern the type of reading behavior? What features should be extracted from the raw gaze data to perform the classification? So far, there are only few researches regarding the use of machine learning to classify the reading patterns in real world scenarios.

In one of the researches, a low-cost eye tracker was employed to record the eye movements during the reading

process. A dispersion-based algorithm is implemented to identify fixation from the recorded data. Features pertaining to fixation including duration, path length, landing position and fixation direction are extracted for classification purposes. Five categories of reading pattern have been defined and investigated in this study, namely, speed reading, slow reading, in-depth reading, skim-and-skip, and keyword spotting. We have recruited thirty subjects to participate in our experiment. The participants are instructed to read different articles using specific styles designated by the experimenter in order to assign label to the collected data. Feature selection is achieved by analyzing the predictive results of cross-validation from the training data obtained from all subjects. The average classification accuracies in five random tests are 78.24%, 74.19%, 93.75%, 87.96%, and 96.20% respectively [3]. To compare with this research, we will use different feature set with similar classifier algorithm type aiming to produce better reading pattern recognition results, while focusing only to binary classification recognizing only quick-readers and slow-readers. Our aim is performing the classification without apriory knowing the time axis and sampling rate of the eye tracker to see if the reader behavior is structurally different or not.

II. DATA ACQUISITION AND PREPROCESSING

For this experiment, we have selected 5 total volunteered participants. Each participant was asked to read two types of articles, while each contained 3 paragraphs. Every paragraph had the same length, consisting of approximately 3 lines of text. We have used each paragraph as single gaze input data later in the experiment. Used articles were in Slovak language and represented a part of some publications from Slovak digital news platforms available online.

To acquire the gaze data for each reading pattern, we have divided our experiment into two parts. For the first article, each participant was asked to read the text freely. However, before moving to the second article, participants have been informed that they would have to answer questions about the paragraphs they read toward the end of the experiment session. This part was intended to gather the information for Slow-reading pattern class, while the first article results were marked as Quick-reading styles.

The screen used was a 19 inch LCD and was set to a resolution of 1920 by 1080. All the paragraphs were displayed in full-screen and at 130% zoom level. Each participant was instructed to sit on the chair and maintain stabilized head

position about 56 cm away from the centre of the screen. While reading was performed, computer was gathering participant gaze positions by using eye tracking equipment.

We have used Pupil eye tracker device to collect gaze data. Pupil Capture software was used to record the eye movement data and then we exported the recordings using Pupil Player into CSV file. Output CSV file contained information including timestamps, data confidence, world and pupil positions. We filtered the data based on confidence parameter equal or greater than 90%, which defines the accuracy of each recorded gaze point by eye tracker device.

We decided to use only X position coordinates of eye gaze movements as our input data, because X axis during reading contains most information.

We have used two test articles with same length. Slow readers read it in average about 25s (1900 gaze samples) and fast readers about 14s (1000 gaze samples). To eliminate the impact of the time axis and gaze sampling frequency while focusing only to the data structures, we subsampled the data to have always only 200 eye positions.

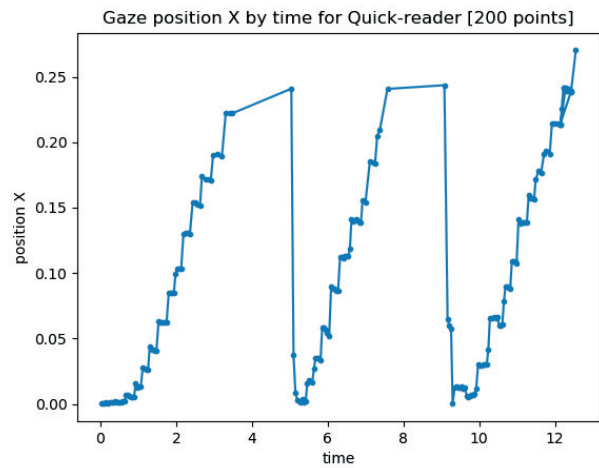


Figure 3. Quick reader example subsampled to 200 points

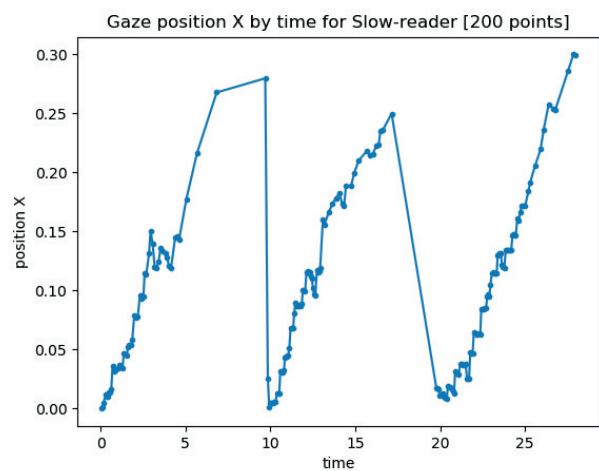


Figure 4. Slow reader example subsampled to 200 points

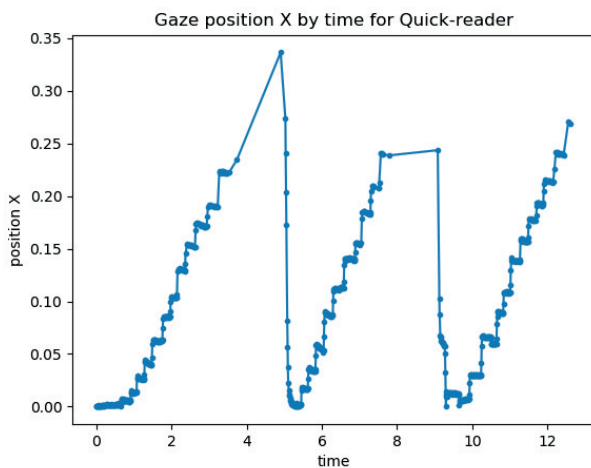


Figure 1. Example data from Quick-reader (910 gaze points).

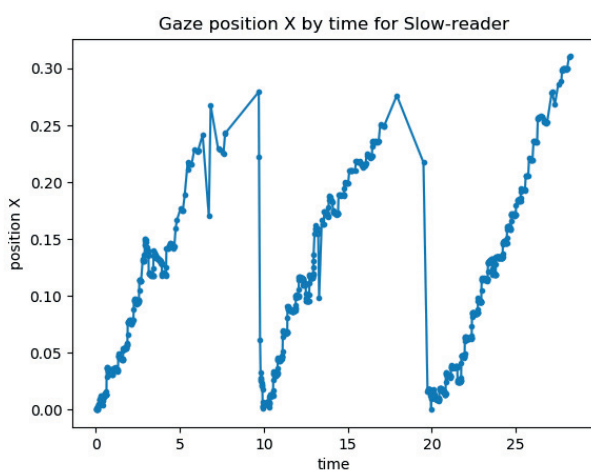


Figure 2. Example data from Slow-reader (1410 gaze points).

III. FEATURE EXTRACTION AND CLASSIFICATION

Based on x coordinates input set, we have used clustering method to detect number of clusters per each set, and average cluster count, which are the two main features for our classification model. The clusters approximately represent gaze fixations, however they also contain nearby lying saccades as for our simple model is not important to distinguish between fixations and saccades. We chose as the main feature the average cluster size. As the number of gaze samples is fixed the average cluster size and number of clusters are dependent.

We have used two methods to define the number of the clusters. These are: manual method and K-means based silhouette clustering algorithm for finding optimal number of clusters. Manual method means manually counting the number of clusters, based on generated normalized graphs from recorded gaze data (see Figure 5 for an example). Example of clusters found by K-means clustering algorithm, for optimal K is shown on Figure 6. Using the methods we have obtained quite similar results for average cluster size.

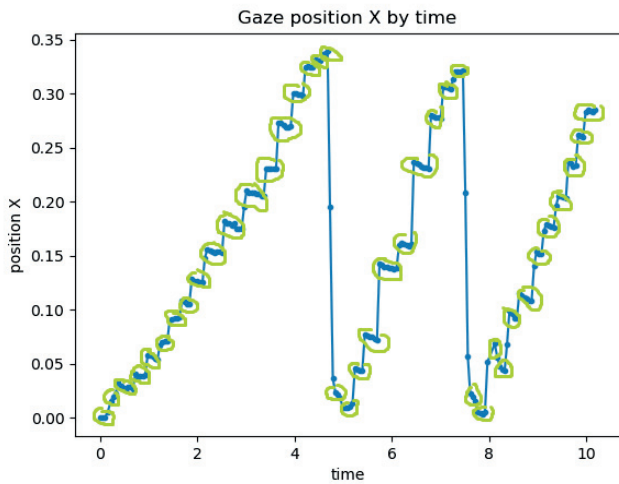


Figure 5. Example of manual clustering method, clusters=40, gazePoints=200, points/per cluster in average=5

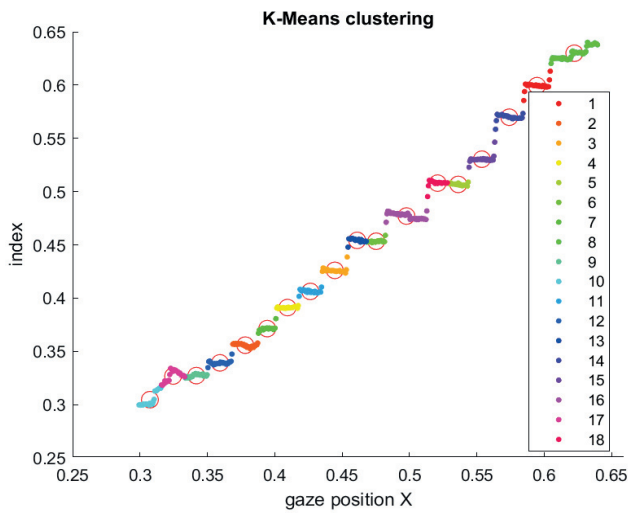


Figure 6. Example of K-mean clustering for K=18

IV. RESULTS

Based on the selected feature, we can construct the positioning of basic features Reading time and Cluster count as in figure 7. We can see, that even if we would know the reading time in our analysis, that feature does not separate the fast readers from slow readers as well as average cluster size (which corresponds with cluster count). This is our primary finding. The classification process than be done using various classifiers. As an example we provide results using KNN and SVM classifiers on figures 8 and 9. In the examples we used 2D based classification. Though this 2D feature set performs well, it is clearly visible that by using only one feature - cluster count can bring better results.

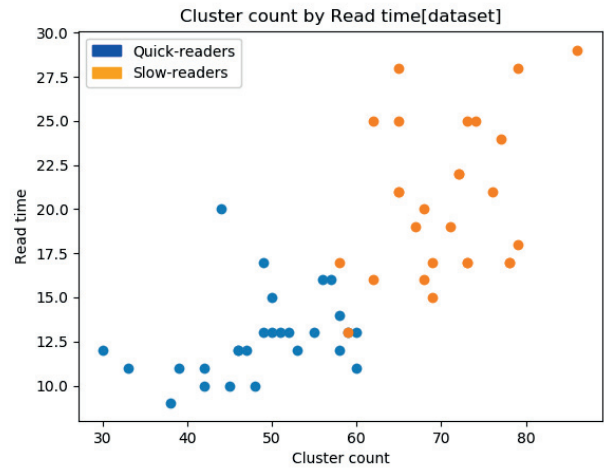


Figure 7. 2D positioning of features for the used dataset

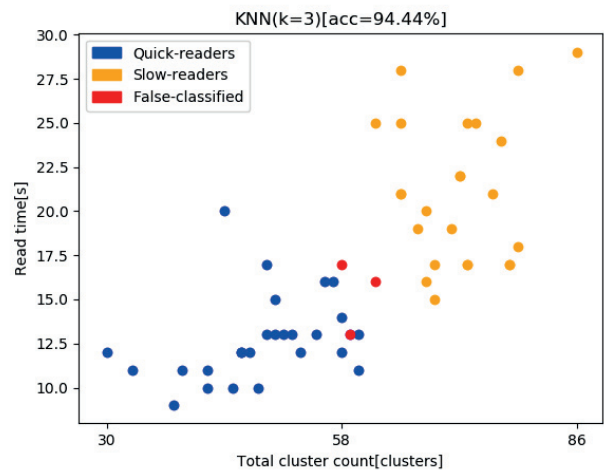


Figure 8. Example classification using KNN

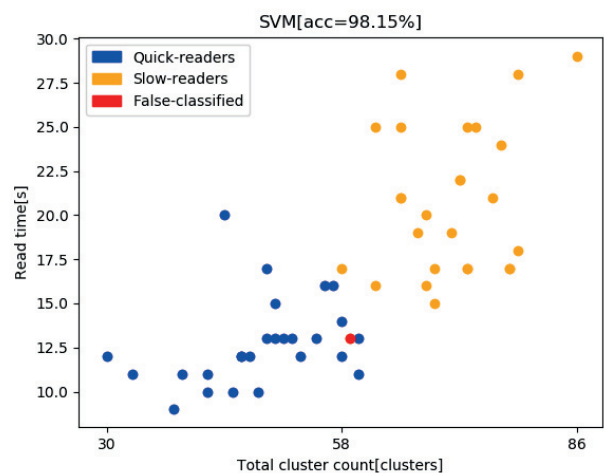


Figure 9. Example classification using SVM

V. CONCLUSION

We demonstrated the feasibility of utilizing gaze information recorded by eye trackers to analyze and distinguish common reading styles (slow readers, fast readers) using feature based on gaze position clustering. This method even outperforms classification based on the time of reading. The method is fast and reliable. The approach can be extended to more complex questions, while more complicated features and higher dimensions can be used. Similar approach could also include saliency map analysis, but it would include much more computational effort.

ACKNOWLEDGMENT

The research presented in this paper was financially supported by VEGA 1/0440/19 and H2020 NEWTON Ref. No.: 688503.

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