ANALYSIS OF TEXT LAYOUT QUALITY USING WEARABLE EYE TRACKERS

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ABSTRACT

How would considering the aesthetics of text layout, particularly line spacing with the *Golden Ratio* (GR) parameter, influence the ease of reading and retention? To answer this question we introduced a novel method by employing a wearable eye tracker instead of a table-mounted eye tracker. Because of their lower price, portability, and growing market, as well as convenience to setup, such head-mounted devices are suitable use for ubiquitous reading behavior analysis. For mapping gaze information from captured video scenes to the original document, we adopted the Locally Likely Arrangement Hashing (LLAH) method for robust document retrieval. In our experimental system, participants read digital documents from the screen with and without the aesthetic GR parameter. Then, gaze data captured by the eye tracker's embedded camera is mapped to the corresponding original document. Finally, our gaze analysis system extracts the intended information for statistical evaluation. Regarding to the results, significant differences in reading performance were found in the documents with and without the GR aesthetic parameter for line spacing.

Index Terms— the *Golden Ratio*, wearable eye tracker, LLAH, reading performance, text layout, line spacing

1. INTRODUCTION

The advance of recent digital devices such as e-books readers, tablets, smart phones, and PCs alongside growing use of the Internet has increased the volume of digital documents that we read from screen. If we can identify some ways of presenting text on screen which facilitate more effective reading, this may ultimately reduce the amount of documents we print from screen [1]. Moreover, in [2] the authors demonstrated high quality typography appears to induce a positive mood. They have shown the differences between good and poor typography that appear to have effect on common performance measures such as reading speed and comprehension.

The Golden Ratio truly is unique in its mathematical properties and pervasive in its appearance throughout nature. In mathematics, as shown in Figure 1, two quantities are in the golden ratio if their ratio is the same as the ratio of their sum to the larger of the two quantities [3].

$$\frac{x+y}{x} = \frac{x}{y} \equiv \varphi \tag{1}$$

where the Greek letter phi represents the golden ratio. Its value is:

$$\frac{1+\sqrt{5}}{2} \approx 1.618 \tag{2}$$

It would be interesting to examine this golden parameter for text layout analysis and human attention on document reading. The illustration of the GR for line spacing is also presented in Figure 1.

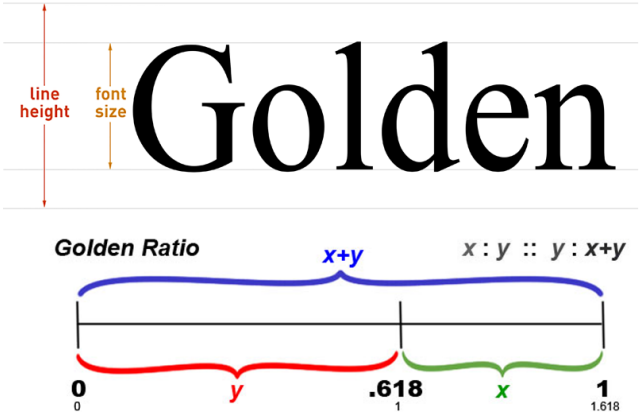


Fig. 1. The Golden Ratio principle for line spacing.

Human attention on document reading is one of the main topics in the eye tracking research over several years [4], [5], [6]. Table-mounted eye tracker systems are widely used in the studies of reading behavior [7] [8] [9] [10]. Nowadays, with the rapidly growing eye tracking technologies, eye trackers have became small, light-weight and wearable, as shown in Figure 2, opening opportunities to extend the scenario to more pervasive scenes.

In this paper, by using a wearable eye tracker, we compared two types of document layouts. One of them carries the aesthetic parameter of line spacing by applying the GR, proportional to the font size, whereas the other has different

line height. The documents have been shown to the participants on a screen. The eye tracking system captured the video scenes of reading and recorded the gaze data. Then, by using a document retrieval system, we mapped gaze data to the corresponding document in our database. Finally, the eye tracking features has been extracted from these raw data for our analysis.

The paper is organized as follows: In section 2 we will explain the methodology of measuring reading behavior with a wearable eye tracker. In section 3 the experiment process will be discussed. Our results are presented in section 4. Finally we conclude our work in section 5.

Fig. 2. SMI ETG Eye Tracker used in our study.

2. MEASURING READING USING A WEARABLE EYE TRACKER

We employed SMI ETG 1.0 eye tracker for the experiment. In brief, the eye tracker has an embedded camera to record scenes during eye tracking experiment. There is a need to retrieve the corresponded document from the video records of reading trials. Then, the raw gaze data will be mapped to the retrieved document. Later, the gaze analysis system extracts intended features for investigations.

2.1. Eye Tracking

The eye tracking is processed using images from two infrared eye cameras and one scene camera. Each eye is illuminated by six infrared lighting sources and the system tracks the changes of these six infrared light reflections. In order to use this eye tracker, the wearer has to calibrate the system. The calibration process requires the wearer to look at one (or three, if necessary) point(s) in a real scene. The process does not take long for most of users, however it sometimes takes very long for other users, when they have difficulties to process it once, thus they have to recalibrate it several times until accurate calibration is obtained.

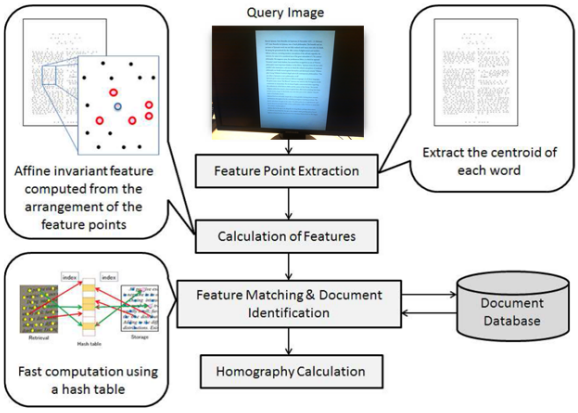


Fig. 3. An overview of the document retrieval (LLAH) process. [11]

2.2. Document Retrieval

We adopt an image based document retrieval method proposed in [12]. This method, called LLAH (Locally Likely Arrangement Hashing) is robust to perspective distortion of an image and scale-invariant. The method has been used by [11]. An overview of the document retrieval method is shown in Figure 3. Here is a brief description of the method: When a scene image is given from the camera, by a Gaussian kernel the image is blured and adaptively thresholded into a binary image in order to detect the centroid of each word region. By changing the size of the Gaussian kernel, it can be adjusted the optimal image blur for document retrieval. From the arrangements of the detected centroids, affine invariant feature vectors are calculated. The recognition process is done by matching the extracted features to the features previously stored in the database. A hashing technique is used for fast computing. By matching the features between the scene image and the retrieved database image, we also calculate the homography between them. Based on this homography, as shown in Figure 5, the gaze on the scene image can be mapped to the gaze on the retrieved document image.

2.3. Gaze Analysis

The gaze analyzer receives the gaze data from the document retrieval module. As a result, the gaze position of the currently read document has been obtained. Here, the parts of text in which gazes are located have been mapped to the coordinates of the retrieved document. From these raw gazes our analysis system first remove noise and then detects *fixation* points. A fixation is defined as gaze appearance in an area of 40 pixels for at least 3 millisecond. Then, the analysis system parses through the fixations into forward reads to calculate the forward movements in the text, *saccades* and

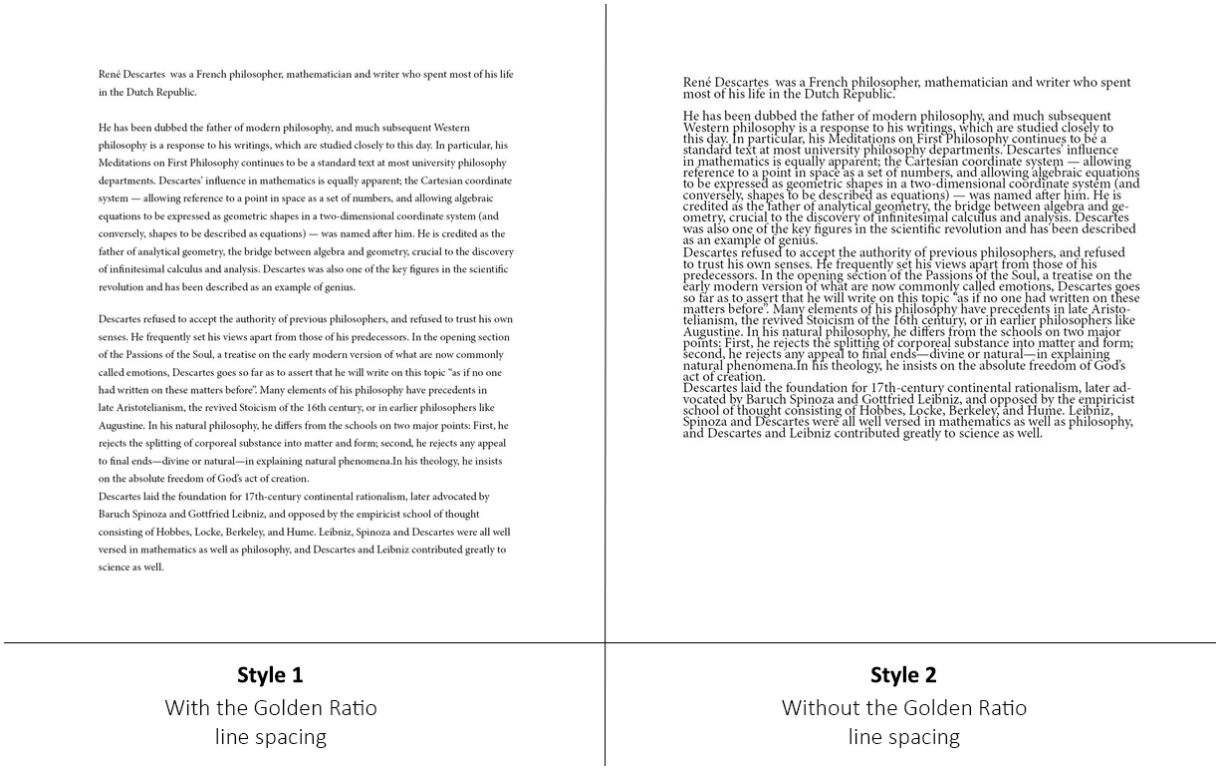


Fig. 4. Style 1 - With the Golden Ratio line spacing vs. Style 2 - Without the Golden Ratio line spacing.

the backward movements, *regressions*. A regression is an implicit sign that the reader is having difficulty understanding the material. In addition to these features, we also recorded *reading time* for each trial as well as evaluated questionnaires for *retention* analysis. Figure 6 shows the output of our gaze analysis system.

3. EXPERIMENT

Our experimental system is designed to record and analyze reading session from the screen. We employed two different texts, containing short biographies of two philosophers: Ren Descartes (**Document 1**) and Baruch Spinoza(**Document 2**). To retain the text difficulty harmony between our experimental articles, we selected the text from the English wikipedia encyclopedia. As shown in Figure 4, Each of the articles carries two different styles of line height.

Style. 1: The proportion of line height to the font size is 168.1 percent. (the Golden Number ≈ 1.618).

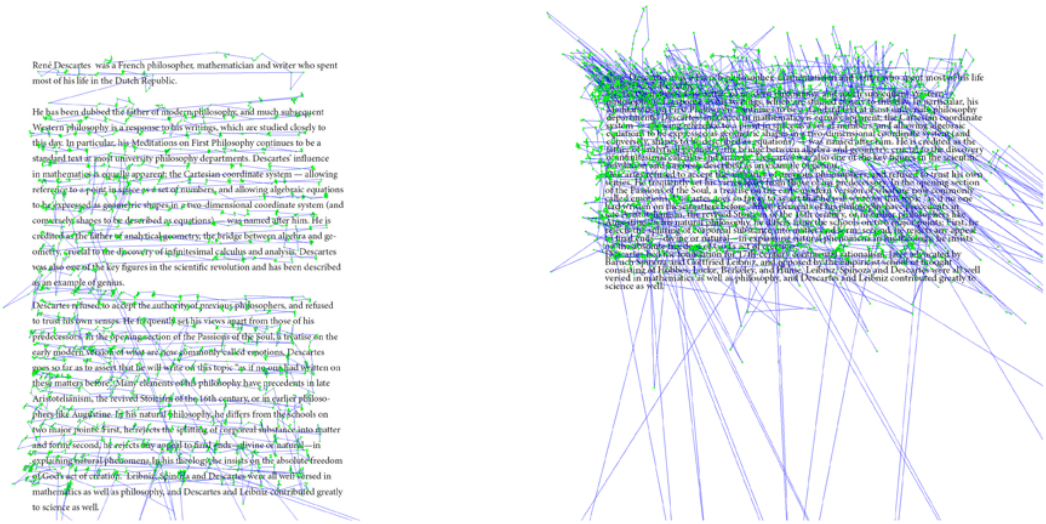
Style. 2: The proportion of line height to the font size is 80 percent.

The font used was Minion Pro 12 pt, and the documents are in JPEG format with 1653x2339 pixel size.

We used SMI Eye Tracking Glasses (ETG) for our study (Figure 2). The temporal resolution of the eye tracker is 30 Hz (binocular) and gaze position accuracy is 0.5 over all distances. The resolution of the scene camera is 1280×960. 10 Participants positioned 50-60 cm from the 21 inch LED screen. Half of the subjects were asked to read Document 1 with style 1 and Document 2 with style 2. Whereas for the rest, the Document 2 with Style 1 and the Document 1 with style 2 were used. To examine retention of reading, two questionnaires, each containing 6 questions for Document 1 and Document 2, are provided. Figure 4. shows the two different style of Document 1. It is clearly visible in Figure 6 that participants had more difficulty in reading Style 2 as comparison Style 1. However, we have computed this fact statistically in the result section.

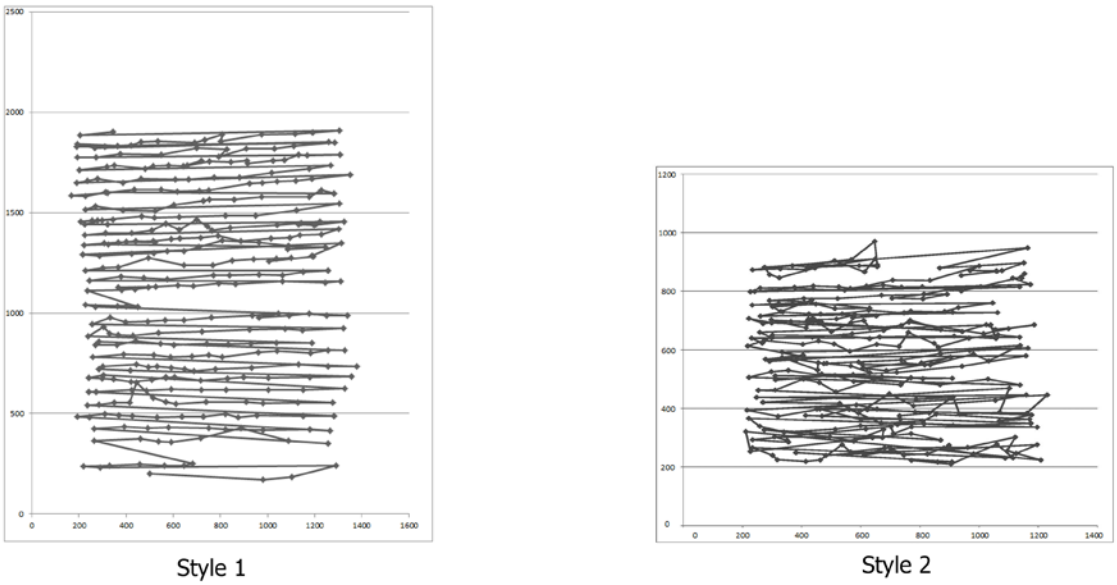
4. RESULTS

To answer "How would considering the aesthetics of line spacing, particularly the GR parameter, influence the ease of reading and retention?", we addressed four features for simple statistical comparison between the two different aesthetic styles in our experiment. These have been constructed from our gaze analysis system. The features are: average reading time, regression ratio, number of fixations, and retention evaluation.



The output of LLAH algorithm

Fig. 5. The output of LLAH algorithm for two different styles



Fixations extracted after gaze analysis

Fig. 6. The output of Gaze Analysis module

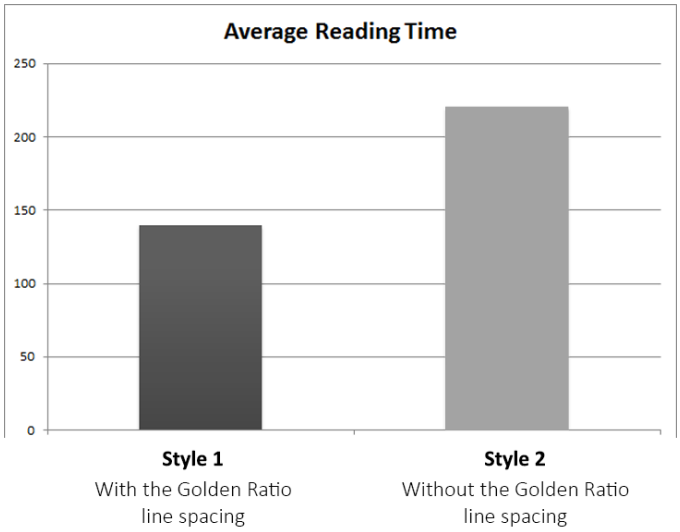


Fig. 7. The time average for trials with Style 1 (Golden Ratio) and Style 2

4.1. Average reading time

The average reading time in trials with the GR parameter (style 1), as shown in Figure 7, is less than the other trials (Style 2). The average values for the first trials (Style 1) was 139.4 second and for the second trial (Style 2) was 220.6 second.

4.2. Regression ratio

The Regression ratio for each documents with two style has been calculated as the appearance average in each categories: Document1 - Style 1, Document 2 - Style 1, Document1 - Style 2 and Document 2 - Style 2. The result shows that the average regression ratio in style 2 documents without the GR parameter is bigger compare to Style 1 for both documents. The result is presented in Figure 8.

4.3. Number of fixations

Similar to the regression ratio, the number of fixations for each document and each style has been calculated as the average appearance in each category: Document1 - Style 1, Document 2 - Style 1, Document1 - Style 2 and Document 2 - Style 2. The results show that the average fixation count in style 1 documents with the GR parameter is lower than Style 2 for both documents. The results are presented in Figure 9.

4.4. Retention evaluation

To determine the retention of reading for each participant, the questionnaires given after the trials were evaluated. The average result of trials with Style 1 with the GR parameter of line

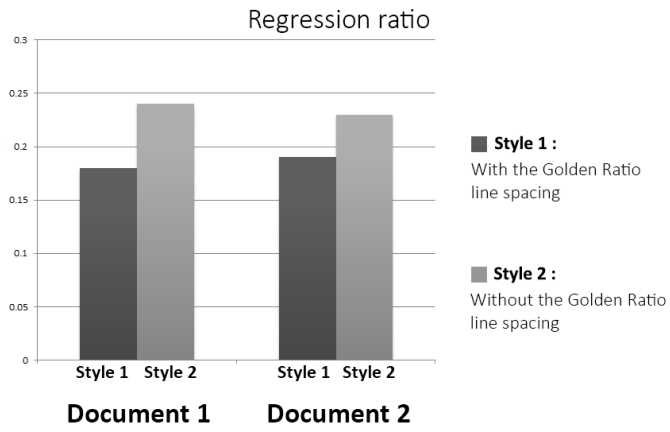


Fig. 8. Regression ratio for trials with Style 1 (Golden Ratio) and Style 2 in the two documents

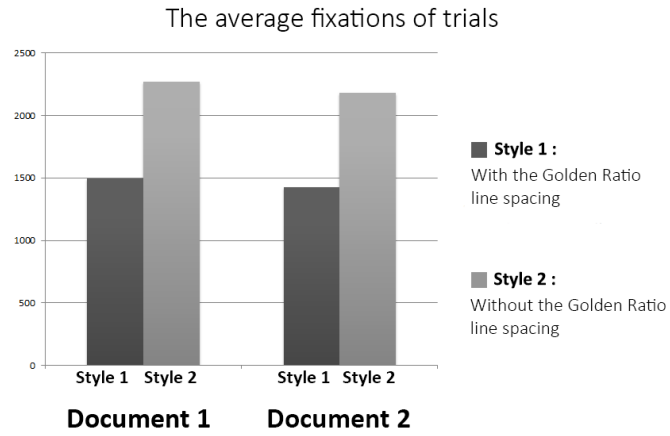


Fig. 9. The average of fixations for trials with Style 1 (Golden Ratio) and Style 2 in the two documents

spacing and trials with Style 2 without the mentioned parameter have been compared. As shown in Figure 10, the participants' answers to the questions are more correct for Style 1 trials than style 2.

5. CONCLUSION

In this paper we proposed novel eye tracking method by integrating the wearable eye tracker and LLAH document retrieval algorithm to evaluate ease of reading by applying the Golden Ratio for line spacing. We found that line spacing parameter of text layout, significantly, influences the reading behavior. Regarding the fact that the main contribution of our paper is to use wearable eye trackers for reading behavior analysis, at this step of research, we used simple statis-

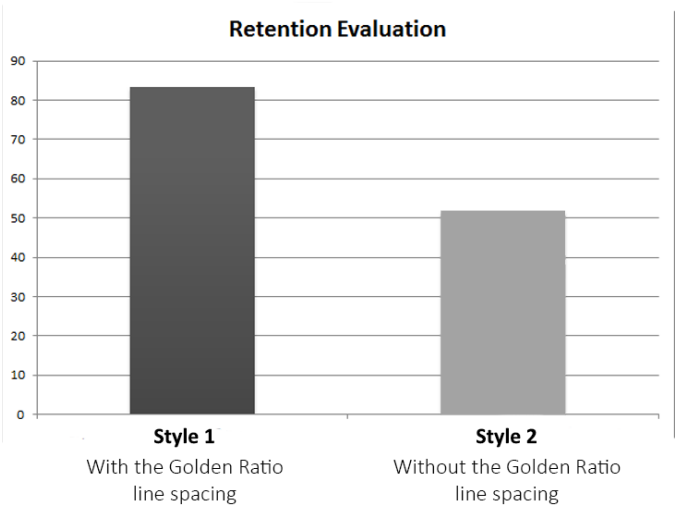


Fig. 10. The retention evaluation for trials with Style 1 (Golden Ratio) and Style 2

tics to evaluate our system. In the future, machine learning approaches are intended for other similar experiments. Although we chose digital documents on screen for our analysis this work is also applicable for printed documents. Indeed, this work has the potential to be extended for further text layout analysis as well as objective text quality measurement.

6. ACKNOWLEDGEMENT

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7. REFERENCES

[1] M. C. Dyson, "How physical text layout affects reading from screen," 2004, Behaviour and Information Technology, Volume 23, Issue 6, 2004, pages 377-393.

[2] K. Larson and R Picard, "The aesthetics of reading," 2005, Appears in Human-Computer Interaction Consortium Conference, Snow Mountain Ranch, Fraser, Colorado, 2005.

[3] M. Livio, "The golden ratio: The story of phi.," New York: BroadwayBooks. Prentice Hall, 2003.

[4] D. Beymer, D. Russell, and P. Orton, "Eye movements in reading and information processing: 20 years of research and eye tracking," Psychological Bulletin, pp. 372422, 1998.

[5] G. Buscher, A. Dengel, R. Biedert, and L. V. Elst, "Attentive documents:eye tracking as implicit feedback for information retrieval and beyond," *ACM Transactions on Interactive Intelligent Systems (TiiS)*, vol. 1, no. 9, pp. 22–25, Jan. 2012.

[6] T. Toyama, A. Dengel, W. Suzuki, and K. Kise, "Increasing the user's attention on the web: using implicit interaction based on gaze behavior to tailor content," Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design Pages 544-553, 2012.

[7] R. Biedert, A. Dengel, M. Elshamy, and G. Buscher, "Towards robust gaze-based objective quality measures for text," Proceedings of the Symposium on Eye Tracking Research and Applications, Pages 201-204, 2012.

[8] R. Biedert, A. Dengel, M. Elshamy, and G. Buscher, "An eye tracking study of how font size and type influence online reading," Proceedings of the 22nd British HCI Group Annual Conference on People and Computers: Culture, Creativity, Interaction - Volume 2, Pages 15-18, 2008.

[9] D. Beymer, P. Z. Orton, and D. M. Russell, "An eye tracking study of how pictures influence online reading," Proceedings 11th IFIP TC 13 International Conference, Rio de Janeiro, Brazil, September 10-14, 2007.

[10] D. Beymer, D. M. Russell, and P. Z. Orton, "Wide vs. narrow paragraphs: An eye tracking analysis," Proceedings IFIP TC13 International Conference, Rome, Italy, September 12-16, 2005.

[11] T. Toyama, A. Dengel, W. Suzuki, and K. Kise, "Wearable reading assist system: Augmented reality document combining document retrieval and eye tracking," 12th International Conference on Document Analysis and Recognition, 2013.

[12] T Nakai, K. Kise, and M. Iwamura, "Use of affine invariants in locally likely arrangement hashing for camera-based document image retrieval," Proceeding 7th International Workshop, DAS 2006, Nelson, New Zealand, February 13-15, 2006.