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Framework for Dynamic Text Presentation in eLearning

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Abstract

We present the framework of an eLearning environment that can adapt to a student's reading behaviour by dynamically selecting and presenting text-based learning material. The student's eye gaze would be used to predict their comprehension level and the text difficulty will be altered to reflect this. This can be used to influence how students interact with the learning environment as well as how they learn the material, streamlining the learning process and optimising learning outcomes. For this framework to be viable two aspects of the design must be feasible; the first is that reading comprehension can be predicted from the reader's eye movements and the second is that changing text difficulty has an effect on learning behaviour. We present preliminary results from a study investigating the latter aspect that supports this claim.

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1. Introduction

Educational material is offered more frequently through online mediums. In tertiary education, face-to-face education is now heavily supplemented with material that is available through online learning environments, such as Moodle and Blackboard. It has become common for universities to offer online/off-campus degrees where students may have little or no face-to-face interaction with their instructors or other students. The need for additional forms of student monitoring will be useful to detect when a student is under- or over-performing so that they can either be given remedial help or advanced material.

Eye tracking has been shown to be an effective way of analysing human behaviours, particularly reading (see review by Rayner (1998)). Given that a primary form of educational material is text, this raises the question of how eye tracking can be used to make the learning process more effective when an instructor has little or no interaction with students. We propose that eye tracking can be used to make informed decisions about how to optimise learning

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outcomes in online learning environments. In this paper, we present the framework for a dynamic text presentation system that uses eye tracking to predict what text should be shown to students. In order to realise the potential of this framework two factors must be feasible; the first is that reading comprehension can be predicted using eye tracking, which is ongoing research for the authors. The second is that changing the text difficulty has an effect on learning outcomes. In this paper we present preliminary results from a user study conducted to investigate the second factor. We conclude with the directions of future research needed to accomplish this framework.

2. Eye Tracking in Adaptive eLearning

During reading the eyes move in a unique way. This is characterized by frequent stopping to taking in visual information, termed a fixation, and fast ballistic movements to proceeding fixations, termed saccades. When reading English fixation duration ranges anywhere between 60-500 milliseconds but are generally about 250 milliseconds. Saccades are between 1 and 15 characters with an average of 7-9 characters (Rayner, 1998). The majority of saccades are to transport the eye forward in the text when reading English. Backward saccades are termed regressions, which can occur due to comprehension difficulties (Rayner, 1998). Eye movements have been shown to reflect global text difficulty as well as inconsistencies within text (Rayner et al., 2006).

Electronic text, eText, is the general term for digital presentation and storage of text. In general, there is little evidence paper versus digital presentation of text, or vice versa, is better in terms of improving comprehension (Dillon and Gabbard, 1998). However, eText has advantages over paper presentation, which include increased accessibility, easy storage and retrieval, ubiquity, and changeability. Changes can be simple, such as, font size, colour, or typeface or they can be more complex, such as verbalisations of the text, embedded definitions and links to background information. There is no consensus which supports, if any, are should be provided and in what combinations (Anderson-Inman and Horney, 2007).

Eye gaze patterns have been used to detect whether a person is reading or not (Campbell and Maglio, 2001) as well as if they are reading or skimming (Buscher et al., 2008). The use of eye tracking in adaptive learning systems (ALS) has been approached in a number of ways. An example of this is iDict, a reading aid designed to help readers of a foreign language (Hyrskykari et al., 2000). iDict uses eye gaze to predict when a reader is having comprehension difficulties. If the user hesitates whilst reading a word then a translation of the word is provided with a dictionary meaning. Another example is The Reading Assistant (Sibert et al., 2000) that uses eye gaze to predict failure to recognise a word. The Reading Assistant then provides auditory pronunciation of the word to aid reading. These applications work on the assumption that the user pauses on a problematic word, and then the system provides feedback about that word rather than overall text comprehension.

In prior work we have established a basis for the detection of participants' topic familiarity (Copeland and Gedeon, 2013a). Furthermore, we defined answer-seeking behaviour as a measure to describe how difficult participants found text and questions and as a measure for feedback to authors about the reading difficulty of the material (Copeland and Gedeon, 2013b). Finally, we have shown that reading comprehension scores can be predicted with artificial neural networks (Copeland et al., 2014). We use this research as the basis for the development of a predictive selector of text that adapts to student's current learning state.

3. Adaptive Text Presentation based on Eye Gaze

The framework for dynamic selection of text based on predictions made from eye gaze is presented in this section as is shown in Figure 1. Eye movements will be used to predict comprehension and the text will be presented based upon the level of comprehension. The hypothesis is that changes to the difficulty of the text (in regard to concepts and readability) will improve students' learning outcomes. In such a system a commercial eye tracker would be used.

Calibration Mechanism: There is a need to account for error in recorded gaze location as it has been documented that eye trackers can lose precision during periods of use (Hyrskykari, 2006). We propose using the calibration techniques described by Hyrskykari (2006).

Pre-processor Mechanism: The output from eye trackers is x-y coordinate time series data, which is sent to the pre-processor mechanism to convert into eye movement measures. Pre-processing is necessary as it is the eye

movements that can be used to make inferences about reading behaviour. The output from the pre-processor is sent to the predictive agent.

Predictive Agent: The predictive agent is one of the two major components of the framework. The predictive agent is based on prior research described in Section 2. The predictive agent uses an artificial neural network (ANN) that is trained to predict comprehension based on eye movements measures. The agent will be extended to include ANN predictors for perceived understanding, engagement, and familiarity. The student's learning history is also used to calculate the student's current learning state. The output of predictive agent is given the content selector.

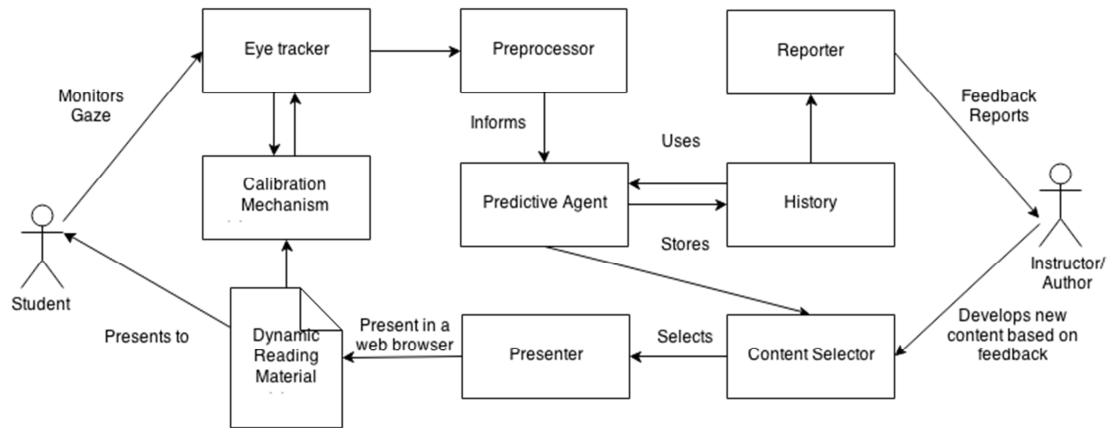


Figure 1. Framework for Dynamic Text Selection

Content Selector: The content selector is the second major component of the framework. The content selector is prefilled with different versions of educational content. The different versions include different levels of readability, concept difficulty as well as remedial and advanced level supplementary material. Based upon the student's current state, as calculated by the predictive agent, a choice of text is made by the content selector. We hypothesise that change in the difficulty of text based on a student's current state can improve learning outcomes. See Section 4 for a preliminary investigation that provides supports this hypothesis. The output of the selector is to the presenter.

Presenter, Reporter, and Student Learning History: The presenter formats the selected content for the learning environment being used, such as Moodle. The reporting system can be used by the instructor to track performance of students as well as to get ratings on difficulty of educational content. The student learning information is stored so that this information can be used in subsequent tutorials, and to track the learning progress.

4. Does Changing Text Effect Learning?

In a preliminary investigation, a small number of participants were asked to read a piece of educational text on computer screen. The topic of the text is digital image. The text covered basic concepts and had a Flesch Kincaid (FK) readability grade level of 11.2. This piece of text is denoted A. The participants then answered two comprehension questions but were not able to reference the text to answer the questions. The total score that the participants could achieve from these questions is 2 and the lowest score is 0. Participants were then shown a second screen of text on the same subject matter. However, the second screen of text was one of two options, denoted B and C. The readability of B was made more difficult compared to A, however, covered concepts at the same technical level as A. The FK readability grade level for B is 15.7. Both readability and conceptual difficulty of C were increased compared to A. The FK readability grade level of C is 14.1. Whether a participant received B or C was a random assignment.

The hypothesis was that the participants who did not achieve full marks for comprehension questions for A will perform worse when shown the text that has both increased readability and concept difficulty (C) compared to when the only the readability is made more difficult (B). Indeed, this is what we have found. The participants ($n=12$) who scored partial or no marks for the comprehension questions for A but were then presented with B, scored on average

1.21 for the comprehension questions for B. In contrast, participants ($n=14$) who scored partial or no marks for the comprehension questions for A but were then presented with C, scored on average 0.86 for the questions for C. Additionally, participants ($n=8$) who achieved full marks for the questions for A but were then presented with B scored similarly to above of the comprehension questions for B which was on average 1.25. However, participants ($n=16$) presented with C after obtaining full marks on A's comprehension questions scored on average 1.6 for the questions for C. Interestingly, these results show that participants presented text with both harder concept and readability performed better on average than those where only the readability was made more difficult.

5. Conclusions and Further Work

We present the framework for a dynamic text presentation system to be used to provide adaptive eLearning material based on eye movements. The notion behind changing the text difficulty to reflect a student's predicted comprehension is that the change will improve the student's learning outcomes. For the framework to be plausible in real world use, two aspects of the design must be feasible. The first aspect is that reading comprehension can be predicted using eye tracking. This has been covered in previous work by the authors. The second aspect is that changing the text difficulty must have an effect on learning outcomes. In this paper we present preliminary findings that confirm this. The results show that if participants did not understand a basic concept but were shown text with increased concept difficulty they performed worse than if shown text with the same concept difficulty but increased difficulty in readability. Further experimental validation of whether changing text difficulty is beneficial to the learning process is needed.

Furthermore, a key area of interest is to investigate the relationship between eye movements and perceived comprehension, confidence, and engagement. In a follow-up study we propose recording eye gaze from participants as they similarly read through a tutorial and quiz. After each tutorial slide we can ask participants for their subjective comprehension as well as other factors, such as confidence, subject familiarity, and arousal.

References

1. Anderson-Inman, L., Horney, MA, Supported eText: Assistive Technology Through Text Transformations. *Reading Research Quarterly* 2007; **42**:153-160.
2. Buscher, G., Dengel, A. & Elst, L. V. Eye Movements As Implicit Relevance Feedback. CHI '08 Extended Abstracts On Human Factors In Computing Systems. Florence, Italy: ACM 2008.
3. Campbell, C. S. & Maglio, P. P. A Robust Algorithm For Reading Detection. Proc. of 2001 Workshop On Perceptive User Interfaces, ACM. 2001:1-7.
4. Copeland, L. & Gedeon, T. The effect of subject familiarity on comprehension and eye movements during reading. Proc. of 25th Australian Computer-Human Interaction Conference: Augmentation, Application, Innovation, Collaboration, 2013;285-288.
5. Copeland, L. & Gedeon, T. Measuring reading comprehension using eye movements. *Cognitive Infocommunications (CogInfoCom)*, IEEE 4th International Conference on, 2013:791-796.
6. Copeland, L., Gedeon, T. & Mendis, S. Predicting reading comprehension scores from eye movements using artificial neural networks and fuzzy output error. *Artificial Intelligence Research*, 2014;**3**(3):35.
7. Dillon, A, Gabbard, R. Hypermedia As An Educational Technology: A Review Of The Quantitative Research Literature On Learner Comprehension, Control, And Style. *Review Of Educational Research*, 1998;**68**:322-349.
8. Hyrskykari, A., Majaranta, P., Aaltonen, A., R ih a, K.-J. Design Issues Of iDict: A Gaze-Assisted Translation Aid. Proc. of 2000 Symposium On Eye Tracking Research & Applications, ACM, 2000, 9-14.
9. Hyrskykari, A. (2006). Utilizing eye movements: Overcoming inaccuracy while tracking the focus of attention during reading. *Computers In Human Behavior*, 2006;**22**(4):657-671.
10. Rayner, K. Eye Movements In Reading And Information Processing: 20 Years Of Research. *Psychological Bulletin*, 1988;**124**(3):372-422.
11. Rayner, K., Chace, K. H., Slattery, T. J., Ashby, J. 2006. Eye Movements As Reflections Of Comprehension Processes In Reading. *Scientific Studies Of Reading*, 1998;**10**:241-255.
12. Sibert, J. L., Gokturk, M., Lavine, R. A. The Reading Assistant: Eye Gaze Triggered Auditory Prompting For Reading Remediation. Proceedings 13th Annual ACM Symposium On User Interface Software And Technology. San Diego, US. 2000;101-107