2009-10-01

Sensing Learner Interest Through Eye Tracking

Haolin Wei
Dublin City University, haolin.wei2@mail.dcu.ie

Arthir-Nicolae Moldovan
National College of Ireland, amoldovan@student.ncirl.ie

Cristina Muntean
National College of Ireland, cmuntean@ncirl.ie

Sensing Learner Interest Through Eye Tracking

Haolin Wei [1], Arghir-Nicolae Moldovan [2], Cristina Hava Muntean [2]

[1] School of Electronic Engineering, Dublin City University, Glasnevin, Dublin 9, Ireland
haolin.wei2@mail.dcu.ie

[2] School of Computing, National College of Ireland, Mayor Street, Dublin 1, Ireland
amoldovan@student.ncirl.ie, cmuntean@ncirl.ie

Abstract

Due to the rapidly growing of the amount of information, a stronger need emerges for efficient and flexible strategies for personalisation of the educational content. E-learning systems are very helpful for learners, however, people differ in knowledge level, learning styles and may seek for different information when they access web based e-learning systems. Therefore, content adapted to the user's needs should be supported by the e-learning systems. In this paper we introduce a new e-learning environment that makes use of eye tracking mechanism to follow learner interest in certain topics and to perform content personalisation. The framework of the e-learning system is presented. Furthermore, an exemplification of the e-learning environment is provided.

Keywords: e-learning, eye tracking, personalised educational content

1 Introduction

With the fast increasing amount of knowledge traditional learning method no longer meet the needs of students and employees, thus improved and efficient learning activities are required. E-learning systems have developed rapidly during the last decade and currently are used in various learning environments such as: schools, home, work and so on. For example distance tutoring systems are used to provide educational content as an alternative to traditional instructor-led learning when face-to-face teaching is not possible. However, learners have different knowledge level, expectations, goals or interests. In order to cope with these problems, and to assist better the learners various solutions were proposed aiming at personalising the educational content. Traditional Adaptive and Personalised e-Learning Systems (AeLS) use different user modelling techniques to personalise a course. User models are created and updated regularly with information that is collected explicit or implicit from the users, through online forms or monitoring their behaviour. Sensing the learners' interest and capturing their behaviour in real time is a challenging task.

In this paper we explore the potential of using eye-tracking technology for sensing learner's interest as well as other contextual information, such as tiredness or confusion. Once detected, this information may be used to improve the personalisation of the educational material, and thus increasing the learning outcome.We also introduce an eye-tracking based AeLS that follows learner's eyes movements to detect their interest and to personalise the educational material.

The remaining of the paper is structured as follows. Research efforts in the areas of adaptive e-learning and eye tracking are presented in section 2. The overview of the proposed eye-tracking based e-learning system and how the system can be used to observe learner's interest in real time is illustrated in section 3. The paper finishes with conclusions and further work.

2 Related Work

As the aim of this project is to observe the learning activity in real-time by monitoring the learner's eyes movements and to adapt and personalise the content, this section discusses current research done in the areas of adaptive e-learning and eye tracking. We also investigate how eyes movement can be combined with an e-learning system to obtain a better adaptive strategy.

2.1 Adaptive E-learning Systems

The first pioneer adaptive Web-based educational system was developed starting with 1995 [1]. This system emerged as an alternative to the traditional "one-size-fits-all" approach in the development of educational courseware. It built a model of the goals, preferences and knowledge of each individual student, and used this model in order to adapt to the student's needs.
Since that time a number of adaptive e-learning systems were developed all over the world, but most of these systems are using various user modelling techniques to perform the adaptation. An example is AHA! (Adaptive Hypermedia for All) which is a generic e-learning system for adaptive course delivery [2]. AHA! uses various navigational and content presentation adaptation techniques (e.g. links hiding). The system detects the links that lead to information that is inappropriate or non-relevant for a particular learner at that time and makes them hidden by presenting them as "normal text".
Another adaptive learning solution uses problem solving software, called problets, to assist the learning, reinforcement and assessment of programming concepts [3, 4]. Each Problet generates problems only for those concepts that the student has not yet mastered. The system is used to describe the programming language domain and monitor which parts the student knows on the basis of his performance and answers.

2.2 Eye Tracking Research Field

In terms of eye tracking technology, eyes movements are indicators of thought involved during visual information extraction [5]. The general eye movement characteristic has been studied in depth during the process of reading [6]. Eyes movements can be roughly divided into two components: *fixations* and *saccades*. Fixations are very low-velocity eye moments that correspond to the subject staring at a particular point. Saccades are rapid eye movements while jumping from point to point in the stimulus [7]. However, more important indicators can be obtained by analysing both components together with other derived parameters, such as regressive saccades (fast eye jumps to reread a selection in text). The regressive saccades are thought to be related to difficulties in processing an individual word, or difficulties in processing the meaning of a sentence [8, 9].

Currently, there are two major methods for eye tracking: Bright Pupil System and Dark Pupil Systems [7]. With the Bright Pupil System the infrared light is shined directly into the eye, coaxial with an infrared sensitive camera, and it produces a glowing effect in the cornea. By tracking the movement of this bright reflection, bright pupil system tracks orbital eye movements. With Dark Pupil System the eye is illuminated by infrared light at an angle from an infrared sensitive camera. The eye and face reflects this illumination but the pupil will absorb most infrared light and appear as a dark ellipse. Image-analysis software is used to determine the gaze position.

Eye-tracking mechanisms were used in different research areas. For example, an adaptive multimedia streaming application [10] has used the eye tracking to find the areas of the multimedia clips the user is watching and to reduce the quality of non interesting areas in order to provide continuity in the streaming and playing process. Search engine may use the eye tracking mechanism in order to analyse user behaviour during the searching process [11]. The eye tracking can also be used as a tool to improve ergonomic design and computer interfaces [12].

2.3 Eye Tracking in E-learning

In order to create and update the user profile in real-time, most of the existing adaptive e-learning systems use various techniques to monitor the learner's browsing behaviour. Such techniques include tracking the page views or the mouse clicks. A proposed framework called AdeLE (Adaptive e-learning with Eye-Tracking) [5] goes further and uses eye-tracking to monitor the learner's behaviour aspects and personal traits, such as learning style, tiredness, objects and area of focus or the time spent on these objects. This solution combines real-time eye-tracking with content tracking analysis for a fine-grained user profiling.
Literature review shows that very little research focused on improving learner profiles by using the real-time eye tracking.

3 Eye Tracking based Adaptive e-Learning System

This section gives an overview over the functional and logical architecture of the Eye Tracking based AeLS, as illustrated in Figure 1. The main functional components are divided into two parts: Client Module and Sever Module.

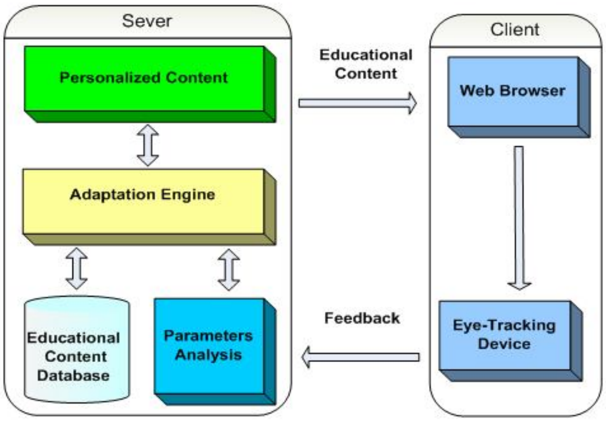

Fig. 1. System Architecture

The Client Module consists of a web browser used for accessing educational content and the Eye Tracking device that collects eye movement data and sends them to the Sever Module.
For the purposes of this project, we used the IView X Red hardware developed by the SensoMotoric Instruments and presented in Figure 2 [13].

Fig. 2. IView X Red eye tracking system

IView X RED is a contact free dark pupil eye tracking system which presents several advantages. First, the system can be easily attached to the bottom of a normal monitor and integrated with applications running on the computer.
As compared to other eye-tracking systems, this solution does not require the users to wear various equipments, and thus it has little impact on the learner and the learning process. In order for the measurements to be accurate, the system requires a calibration to be performed each time a user starts to use it. However the calibration process has a reduced duration, and cannot be seen as an impediment.
Its high tracking quality allows the system to be used by people of all ages, with or without glasses or contact lenses. More technical advantages are the high accuracy (less than 0.4 degree) and high sampling rate (60Hz and 120Hz). A well-designed software interface is provided for analysing learner’s eyes movements.

The IView X software interface (Figure 3) is used to control the eye tracker device and to process the eye image captured by the infrared camera. Once the calibration was done, the IView X will be able to calculate the gaze position (the point where the eye is actually looking on the screen).

The Sever Module is responsible for receiving, analysing and utilizing the eye data. It contains three main components: Parameters Analysis, Educational Content Database and Adaptation Engine.

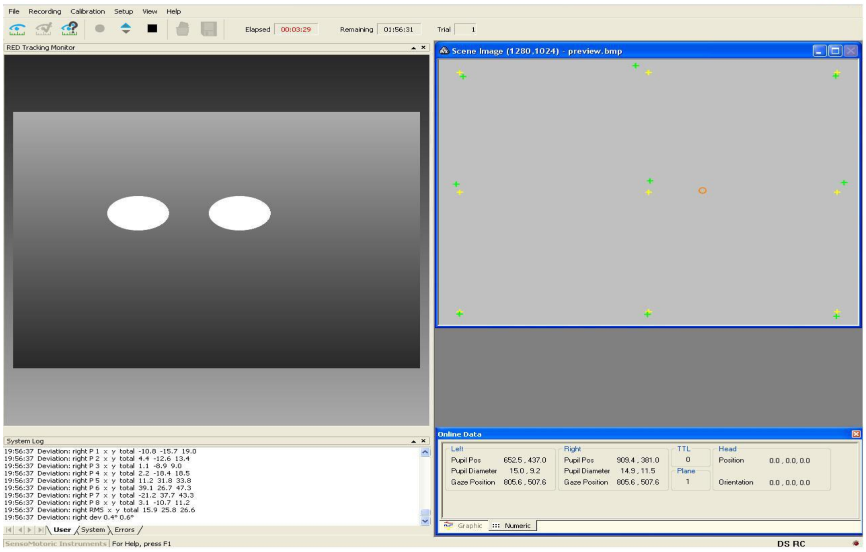

Fig. 3. IView X interface

3.1 Educational Content

The course content used in our study provides an introduction into biology, chemistry, physics and programming subjects. In order to make the learner more focus on certain topics the web pages are divided into four main areas (Figures 4a-c). Each area represents one topic or a sub-topic. When the learner clicks the next button, the adaptation engine will decide the next page to be displayed depending on the learner’s eyes movements and his interest in certain topics. For example, if the learner looks most of the time on the area of the web page that introduces the physics topics (Figure 4a), the eye tracking tool indicates this though a large number of circles in that area. A circle indicates a point of the eyes on the screen. The size of the circle shows the duration of the time spent looking at that position.

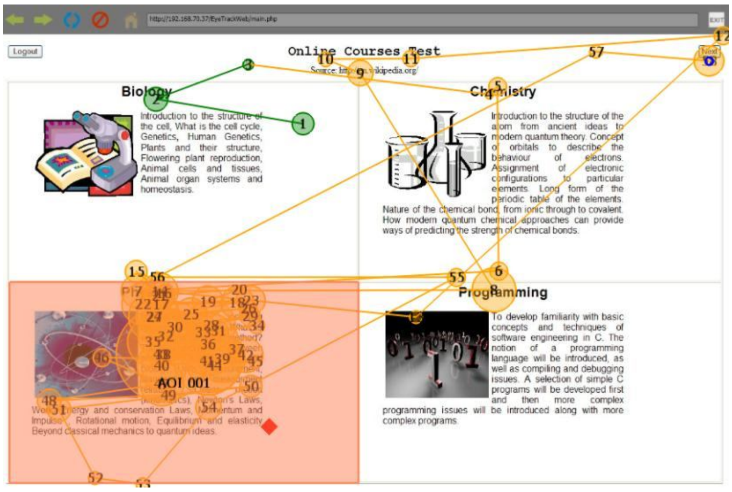

Fig. 4a. Main page consisting of 4 major topics: Biology, Chemistry, Physics and Programming

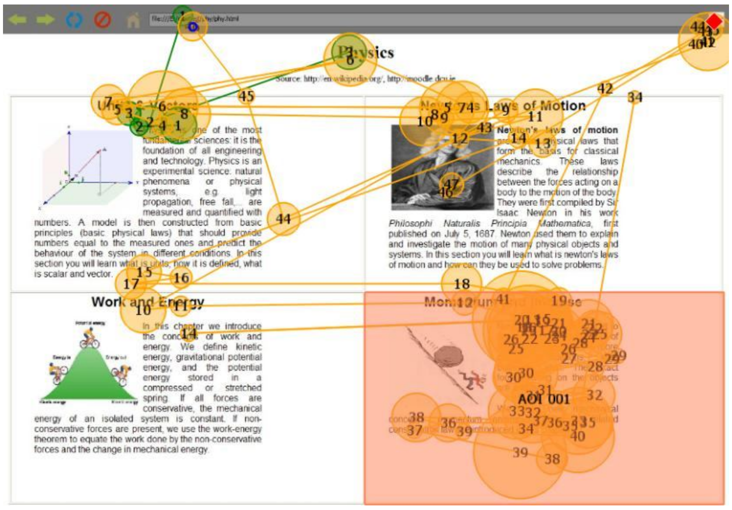

Fig. 4b. The next page (Page 2) displayed to the learner providing more details on the physics topic, the most interesting one for the learner.

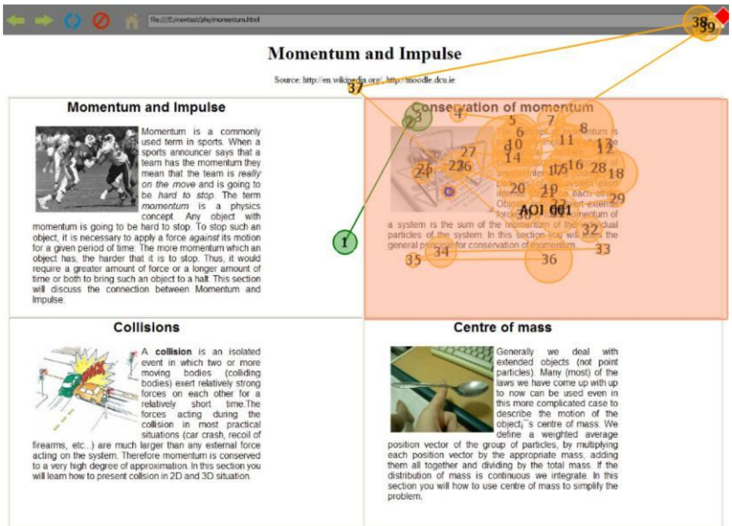

Fig. 4c. Page 3 displayed to the learner providing more details on the Moment and Impulse sub-topic

3.2 Parameters Analysis

As the screen is divided into four areas, a boundary condition can be set for each topic. A program compares each gaze position with the interval and counts the number of samples in each area, depending on which area gets the most samples learner's most interested topic is detected. Further analysis on the learner profile such as learning style, tiredness, confusion can also be performed once the condition is set. For example a learner with a strong visual memory but weaker verbal processing will spend more time on the picture rather than the text. Once the student's learning method is identified, the educational content is adapted to provide mainly images and video, rather then text, and thus increasing the efficiency of the learning process. Regarding tiredness and content difficulties, it is said saccadic velocity decreases with increasing tiredness and increases with increasing task difficulty [5]. When a boundary condition is triggered, the system can interact with the learner to suggest a break or change in the content.

3.3 Adaptation Engine

When learner logs in, the results from the parameters analysis block are saved in the database. Every time when the user starts a course, his behaviour is recorded in the database. This includes when the course is started, which page the learner had visited and how long she/he spends on each area. This data is combined with eye movement to get a fine-grained user profile.

4 Conclusions and Further Work

Nowadays the eye tracking devices can be easily integrated with regular computer monitors used to visualise e-learning courses. Even though the cost of an advanced eye-tracking system is still high, in a couple of years the rapid technical progress may come with low-cost solutions and accurate eye tracking systems. Combining real-time contextual data that can be captured using an eye tracking system with the sophisticated user modelling techniques, a fine-grained user profile can be obtained, thus highly personalised course content can be created for the learners.

Further work will address improvements in the functionality of the proposed AeLS. First, we plan to improve the adaptation model with support for multimedia content. Second, we want to add prediction to the system such as learner's tiredness and confusion. And finally, we are going to perform subjective tests and to compare the results with traditional adaptive e-learning systems and to evaluate if learner experience is enhanced.

Acknowledgements

The support of Science Foundation Ireland and ODCSSS (Online Dublin Computer Science Summer School) programme is gratefully acknowledged.

References

[1] De Bra, P., Brusilovsky, P., & Houben, G. J. (1999). Adaptive hypermedia: from systems to framework. *ACM Computing Surveys (CSUR)*, *31*(4es).

[2] De Bra, P., Smits, D., & Stash, N. (2006). Creating and Delivering Adaptive Courses with AHA! *Lecture Notes in Computer Science*, *4227*, 21.

[3] Kumar, A. N. (2005). Results from the evaluation of the effectiveness of an online tutor on expression evaluation. In *Proceedings of the 36th SIGCSE technical symposium on Computer science education* (pp. 216–220).

[4] Kumar, A. N. (n.d.). Problets - The Home Page. Retrieved September 25, 2009, from http://www.problets.org/.

[5] Gütl, C., Pivec, M., Trummer, C., García-Barrio, V. M., Mödritscher, F., Pripfl, J., & Umgeher, M. (2005). AdeLE (Adaptive e-Learning with Eye-Tracking): theoretical background, system architecture and application scenarios. *EURODL: European Journal of Open, Distance and E-Learning*, 2005–12.

[6] Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological bulletin*, *124*, 372–422.

[7] SensoMotoric Instruments. (2007). An Introduction to iView X. iView X System Manual.

[8] Kennedy, A., & Murray, W. S. (1987). Spatial coordinates and reading: Comments on Monk (1985). *The Quarterly Journal of Experimental Psychology Section A*, *39*(4), 649–656.

[9] Murray, W. S., & Kennedy, A. (1988). Spatial coding in the processing of anaphor by good and poor readers: Evidence from eye movement analyses. *The Quarterly Journal of Experimental Psychology Section A*, *40*(4), 693–718.

[10] Ghinea, G., & Muntean, G. M. (2009). An Eye-Tracking-based Adaptive Multimedia Streaming Scheme. In *2009 IEEE International Conference on Multimedia and Expo (ICME 2009)* (pp. 962 - 965).

[11] Granka, L. A., Joachims, T., & Gay, G. (2004). Eye-tracking analysis of user behavior in WWW search. In *Proceedings of the 27th annual international ACM SIGIR conference on Research and development in information retrieval* (pp. 478–479).

[12] Kramer, A. F., & McCarley, J. S. (2003). Oculomotor behaviour as a reflection of attention and memory processes: neural mechanisms and applications to human factors. *Theoretical Issues in Ergonomics Science*, *4*(1), 21–55.

[13] SensoMotoric Instruments GmbH, Gaze & Eye Tracking Systems - iView X RED (n.d.). Retrieved September 27, 2009, from http://www.smivision.com/en/gaze-eye-tracking-systems/products/iview-x-red-red250.html.