Scan Path Based Approach to Detect Learner's Concentration in Distance Learning System

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***Abstract*— Distance Learning (DL) systems have been growing recently due to the rapid advancement of Information and Communication Technology (ICT). However, each learner, who is attracted to take distance learning courses due to its convenience is always isolated. Therefore, it would be useful to take care of the learners more if the instructor could get information of the learner's condition such as where the learner is looking at and how long the learner takes to look at that particular point. This information is important to detect learners' concentration to the class, and thus it can be used for designing the content style of the class based on the learner's preference. In this study, the novel automatic approach to detect learner's concentration based on the content preference will be proposed. The main goal is to detect each learner's concentration based on the content style in a distance learning class session. In addition, this study will focus on real time distance learning class systems. During a real time class lesson, biological information such as fixation duration, fixation frequency, and saccade will be recorded in the eye tracking system and these data will be analysed. If the number of learners who are not concentrated on the content is larger than a threshold value, the alerting system will send a message to the instructor's display. Therefore, the instructor will change the content style accordingly. The proposed approach will be very useful in assisting the instructor to understand and determine the best content's model style to be used in the distance learning class based on learners preference.**

***Index Terms*—concentration, distance learning, fixation duration, saccade, learner**

I. Introduction

Recently, Distance Learning (DL) systems have received attention in higher learning institutions. DL is a process of teaching and learning where both learners and an instructor are separated by time and distance [1]. It is structured into two parts, namely, synchronous and asynchronous systems. Both have some advantages compared to traditional learning systems due to their convenience. However, physical interaction between a learner and an instructor is missing. Therefore, feedback from learners based on teaching process is very useful for the instructor to adjust their teaching strategy to the learner's condition. Several approaches have been deployed in many studies in order to recognize learner's conditions and provide feedback during learning process, however, most of the approaches have focused on asynchronous distance learning systems. On the other hand, process of teaching and learning in DL system can be improved by considering not only asynchronous but also synchronous distance learning system.

Recently, eye tracking system has been deployed in many studies, in particular, in distance learning systems for detecting learner's condition during learning process [2], [3]. Eye tracking system is a device used for recording eye movements which are controlled by autonomic nervous system. [4] argued that eye movement is associated with brain activities. One of the important parameters which is generated from eye tracking system is scan path, namely, a sequence of fixations. The fixation is a state where an eye is still to extract some information from display, therefore, after the brain captures information from that point, it moves to another point. In addition, movements between fixations is called saccades. In their investigation, Goldberg [5] and Coco [6] stated that scan path is a sequence of fixation and saccades.

The aim of this study is to accurately detect learners concentration in a real time distance learning class session based on learners content preference. In this study, concentration is defined as a situation of learner to direct his/her thinking and focus on the content which the instructor is presenting in the real time class session. Sometimes learners tend to lose their concentration in DL class session due to the content style, e.g. some learners prefer the content style with figures and text while others prefer text only [7]. In order to achieve our goal, eye tracking system will be deployed in this study. Firstly, during a real time class session, learner's eye movements will be recorded in eye tracking system. Secondly, the recorded data from eye tracking system will be analyzed by focusing on two conditions, namely, "concentrated" and "not concentrated". Finally, if the number of learners who are not concentrated on the content is larger than a threshold value, it will be judged that the content style is not suitable for the learners, therefore, the instructor will receive a real time notification from the alerting system on his computer display in order to change the content style accordingly. This technique will be very useful, not only to improve learning process for learners but also for instructors to determine the best content style for the learners.

The rest of this paper is organized as follows: Section II will review the related works in detecting learner's conditions in distance learning. Next in Section III, overview of eye tracking system will be explained. Then

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in Section IV, the proposed system design will be described in detail. In Section V, the evaluation of the proposed method in terms of experimental results will be shown and discussed in Section VI. Finally, in section VII, this paper will be concluded and future work possibilities will be provided.

II. Related Works

Sandanayake and Madurapperuma [8] proposed a computational model for recognizing learner's emotions in distance learning environment. In addition, they developed a tool for recognizing learner's emotions during learning process through an online Achievement Emotion Questionnaire (AEQ). Their approach is useful to identify learner's emotions during learning process as well as learning performance.

Cheng *et al*. [9] proposed a formative assessment approach using data mining techniques which integrate six computational intelligence schemes such as statistics correlation analysis, fuzzy clustering algorithm, grey relational analysis, K-means clustering, association rule and fuzzy inference during learning process in order to evaluate learning behaviors and performance from the learners.

Likewise, Li Li and Wang [10] discussed the design, implementation and application of E-portfolio based performance assessment in distance learning. On their investigation, they found out that, on existing web-search environment, many studies have focused much on learner's qualitative assessment without considering performance evaluation of learner's complex, high cognitive level, learning behavior etc. Also, they declared that performance assessment in distance learning would be useful if learner's performance in the whole learning process will be assessed properly.

Daniela and Georgi [11] pointed out that appropriate method for assessing and evaluating learners' behavior in distance learning class session would be very useful for improving learning process. Furthermore, they declared that learner's behavior during distance learning class session might affect their learning process in some ways.

Hwang *et al*. [12] proposed a web searching environment called Meta analyzer in order to assist instructors in analyzing learner's behavior during learning process. During web search learning environment learner's problem solving behaviors of using search engine were recorded. Their approach is focused on assisting instructors in observing and analyzing learners learning behaviors related to web-search problems.

Charoenpit and Ohkura [13] proposed a new e-learning system focused on an affective aspect and integrated three different biological sensors which includes Electroencephalogram (EEG), Electrocardiogram (ECG) and eye tracking system to measure, detected and analyzed learner's emotions such as boredom, anxiety and anger during learning process and designed the environment and tool to avoid such emotions.

Several approaches have been studied in order to assess learner's behavior in distance learning environment. Most of studies focused on learner's emotions as a factor that may affect learners in learning process. However, the proposed method in this study with real time feedback from learner to instructor has not as yet been studied in existing works. This is because most of existing works have focused on asynchronous distance learning system where there is no interaction between learner and instructor. It is believed that scan path based approach is just a starting point for detecting learner's concentration in a real time distance learning class session based on the content style.

III. Overview of Eye Tracking System

In this study, an eye tribe tracking system has been used in recording learner's eye movements. Fig. 1 illustrates the configuration of an eye tribe tracking system (in a red rectangle) for experiment. The device operates at the frequency of 30 and 60 Hz with gaze accuracy of 0.5 ° of visual angle [14]. The gaze accuracy describes the angular average distance from the actual gaze point to the point measured by eye tracker.

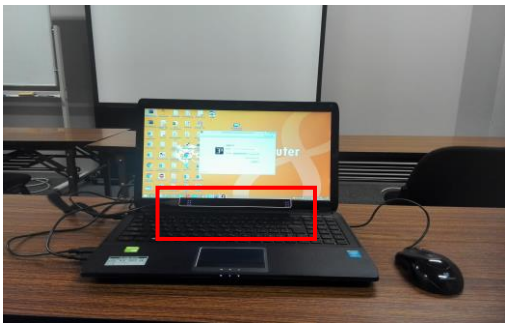

Figure 1. Eye tribe tracking system

The device operation range is 45cm – 75cm and tracking is 40 cm X 75 cm at 65 cm distance from the tracking person. The device was interfaced with computer via Universal Serial Bus 3.0 (USB 3.0) and it uses Cornea reflection technique for recording eye movements as shown in Fig. 2 below [15].

The Cornea reflection technique is a real time image processing to recognize and localize pupil and cornea reflection.

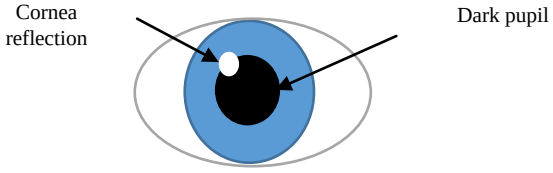

Figure 2. Cornea reflection

When near infrared light (from eye tracker) is directed towards the center of the pupil, it causes visible reflection in the cornea. These reflections are tracked by a camera and eye movements are recorded.

IV. Proposed System Design

Fig. 3 shows the proposed design of distance learning system. A learner is an individual who has registered for

distance learning system. Instructor is the one who is assigned to deliver lecture to the learners in a real time manners. During a real time class session, learners will access information from instructor in content section. During the process, learner's eye movements will be recorded in eye tracking system device. Furthermore, the recorded information will be analyzed focused on two condition from the learner, namely, concentrated or not concentrated. If the number of the learners who are not concentrated on the content exceeds the threshold level, the alerting system will send a message to the instructor's display. Being aware of the message, the instructor will change the content style promptly.

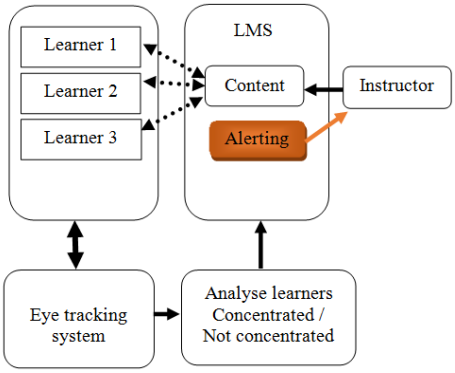

Figure 3. Diagram of the proposed system design

The framework design of the proposed system consists of four main components and two sub components as described below;

A. *Learner 1, 2, 3...*

These are the individuals who registered for distance learning system. Everyone can login on his/her web browser from their computer and access a distance learning class session on a specified time.

B. *Eye Tracking System*

Is a device which is placed on beneath of computer display to record learner's eye movements information during the real time class session and analyze the recorded data to determine if the learner is concentrated on the content or not.

C. *Learning Management System (LMS)*

Is a software application which manages instructors on how to manage documents such as lecture presentation, teaching contents, assignment, quiz and delivery of distance learning course. LMS comprises of two components, namely, content and alerting system.

Content – It is the content style which an instructor is deliver to learners in a real time class session.

Alerting system - this is a system which will send a message on an instructor's computer display for notifying him if more than the threshold number of learners tends not to concentrate on the content.

D. *Instructor*

Has the power to create course content, assignment, quiz and examination as guided by LMS and interact with learners using the LMS.

V. Evaluation

An experiment was conducted in order to evaluate the effectiveness of the proposed method in terms of scan path metric. Before the experiment started the eye tracker was connected to a personal computer via USB 3.0 interface and placed beneath the computer display where the distance from the device to the tracked person was 60 cm. The computer screen resolution was 1600 x 900 pixels and the light intensity of experimental room was set to 120 lux. The experiment involved ten subjects who are students at Shibaura Institute of Technology aged between 25 and 34 years old. Before the experiment each subject was asked if he/she had any visual problem, then the subjects who had no visual problems were selected for the experiment. The subjects were instructed properly on how to use eye tracking system.

In order to detect learner's concentration based on the content style, one content which introduces "Basic HTML" was prepared. The content was considered as simple since all the subjects have a background on HTML, however, the content style was text and few figures. The experiment was conducted to one subject at a time. Before the experiment started, the system calibration was performed using nine dots to investigate the area on the screen where a learner could view. After the calibration finished successfully, the information of each learner eye movements were recorded while concentrating on the content for three minutes. After the experiment finished, each learner completed a questionnaire related to the content in order to confirm whether the content style is proper for them or not. Table I below shows a summary of questionnaire response;

TABLE I. Summary of Questionnaire Response After Experiment

	How do you Rate the content	Did you understood	Any Comment
Subject 1	Easy	Yes	
Subject 2	Moderate	Yes	
Subject 3	Moderate	Yes	
Subject 4	Difficult	A little	
Subject 5	Moderate	A little	
Subject 6	Difficult	Yes	
Subject 7	moderate	Yes	
Subject 8	moderate	A little	
Subject 9	moderate	A little	
Subject 10	moderate	A little	

Table I shows that only one subject rated the content as easy to understand and the rest rated the content as moderate and difficult. Those subjects recommended that the font size should be larger and many figures should be included rather than text so that the content style will be easier for them to understand.

In the experiment, the scan path data generated from eye tracking system were analyzed to determine learner's concentration on the content. The visual scan path obtained from eye tracking system determines where the learner was looking at and how long he/she took time to look at that point. Note that it does not have any information related to mental activity [16]. Due to that, raw data which have been used to generate scan path

visualization was analyzed focusing on fixation duration and saccades. The fixation duration in effective information processing range is between 200 and 600 msec [17]. However, some eye tracking device generates fixation duration below 200 msec. In this study, even the fixation duration was below 200 msec, it was added into consideration. On the other hand, in concentration condition, saccades appear to be visible, in other words, there must be a clear movement between fixations [6]. Fig. 4 illustrates the visual scan path for subject 1 as obtained from the experiment;

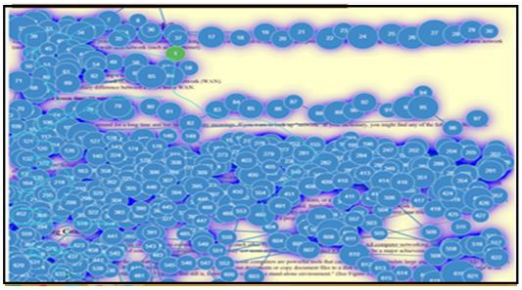

Figure 4. Visual scan path obtained from experiment

From the visualization scan path in Fig. 4, the raw data which have been used to generate fixations were analyzed again in Microsoft Excel by using IF statement function to generate different size of bubble depending on fixation duration.

Fig. 5 shows the analyzed data from the scan path visualization. The size of the bubble indicates the time duration taken to extract information from that particular point. Therefore, the smaller the bubble, the shorter the duration and the larger the bubble, the longer the duration taken to extract information from the display. Results in Fig. 5, shows that the learner was concentrated on the content since the sequence of fixation is clearly identified. However, the result at the bottom of the content shows that the learner had some difficulties in extracting information since the fixation counts appear to be inconsistent and the movements between fixations almost disappear.

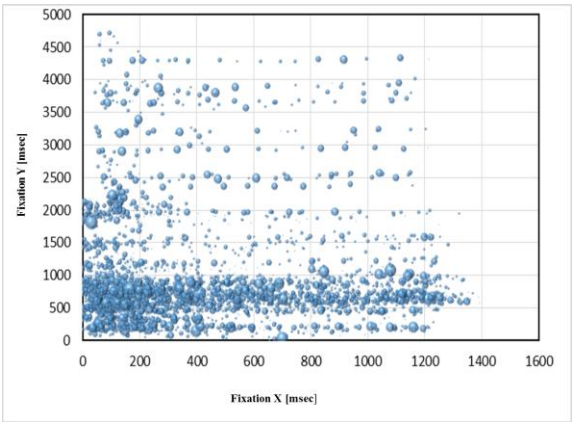

Figure 5. Raw fixations data analyzed from scan path visualization

After that, fixation duration for all data points were analyzed to determine the level of each learner concentration on the content.

After every eighteen seconds fixation duration data points are summed together and average point is calculated. Therefore, for three minutes experiment duration there would be ten average data points. Consequently, the average data points below 600 msec was considered as concentration and above 600msec considered as not concentrated condition. Fig. 6 illustrates the average fixation duration for subject 1. The results show that concentration level is 100% since all average data points are below 600 msec.

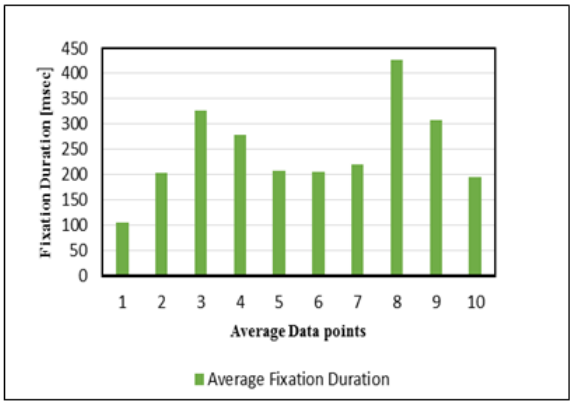

Figure 6. Average fixation duration for subject 1 obtained from experiment

From Fig. 6, concentration level for each subject was calculated by taking average fixation duration less than 600 msec divided by total average fixation duration then multiply by 100 to get the percentage [%]. Consider equation (1) below;

Let average fixation duration less than 600 msec= Y

Total average fixation duration = Y_T

$$\text{Concentration level} = (Y / Y_T) \text{ X } 100 \text{ [\%]} \quad \text{..... (1)}$$

The average fixation duration results for all subjects obtained from experiments show that the concentration level for all subjects involved in experiment was 100% as shown below;

TABLE II. CONCENTRATION LEVEL IN TERMS OF FIXATION DURATION OBTAINED FROM EXPERIMENT

Subject ID	Concentration level in [%]
Subject 1	100%
Subject 2	100%
Subject 3	100%
Subject 4	100%
Subject 5	100%
Subject 6	100%
Subject 7	100%
Subject 8	100%
Subject 9	100%
Subject 10	100%

VI. DISCUSSION

In this paper, a scan path based approach to detect learner's concentration has been proposed. The scan path visualization results obtained from experiment in Fig. 4 determine how the learner viewed the content. It does not imply the level of concentration on the content. Moreover, the scan path raw data contain three parameters which are

fixation duration, fixation counts and saccades. In this study, fixation duration and saccades have been considered as appropriate parameters to detect learner's concentration on the content during a distance learning class session. Furthermore, fixation duration results for ten subjects obtained from experiment have analyzed. The results show that in concentration condition, fixation duration for all subjects were below 600 msec and this has already been confirmed in previous work. Nevertheless, there is still individual difference in eye movement, therefore more suitable time interval for detecting learners concentration in terms of fixation duration should still be studied since the values of 200 and 600 msec are overall interval.

On the other hand, saccades metric which shows movements between fixations has been analyzed. Based on the results in Fig. 5, it is proven that successful visible saccades between fixations implies concentration condition. However, in the bottom of Fig. 5, fixation counts seem to be so scattered. This is because the font size over that area was so small. Therefore, these factors should be added into consideration when designing distance learning content, e.g. font size should be larger enough and distance from the subject to the display should not exceed 60 cm. Nonetheless, in this study, fixation duration has shown some contribution in detection of learner's concentration in distance learning.

Additionally, due to the nature of Distance Learning system, the content style in a class is considered as an important factor to attract the learner's attention. In other words, the content style should be selected in such a way that the learner can easily understand it. Fig. 4 shows that fixation counts in one area are overlapped, that is to say, the learner took a long time to understand the content. This is because the content style used in the experiment was text only. After the experiment, the learner suggested that the content should have been presented with many figures rather than only text. Therefore, when the text content is being used in a class and the proposed system detects that the number of learners who are not concentrated on the content is larger than a threshold value, the instructor will change the content style from text to figures immediately.

VII. Conclusion

In this paper, a scan path based approach to detect learner's concentration in DL has been proposed. From the results obtained by the experiment, it can be proven that some parameters from the proposed method can well detect learner's concentration in a real time distance learning environment.

It is also proven that the sequence of fixation and saccades is clearly identified as analyzed from the raw data. This is regarded as effective information processing in brain during concentration condition. In addition, the fixation duration is considered as a good parameter since the average fixation duration for each subject was below 600 msec.

Currently, the effectiveness of proposed method has been evaluated from only ten subjects. This is considered as a very small number of subjects due to some limitations with the eye tracking system, whereby subjects putting spectacles or contact lenses, their eye movements cannot effectively be detected by the device. Nevertheless, it is believed that with the rapid advancement of technology in eye tracking system, in the near future there might be a mechanism where a device will be able to overcome those limitations.

In the Future, More subjects will be considered and the effectiveness of the proposed method will be evaluated.

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