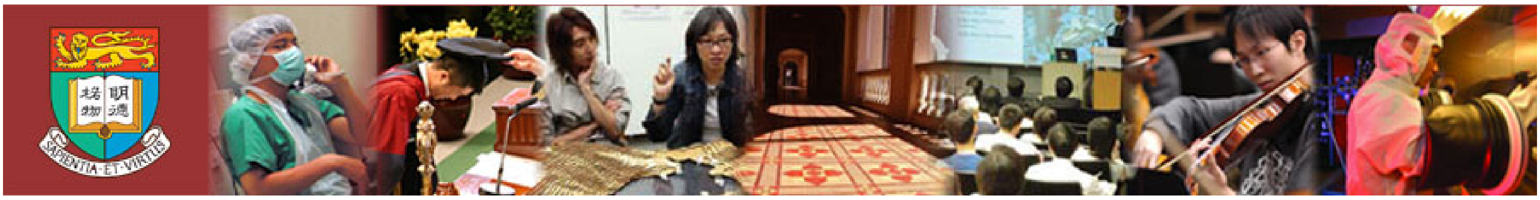

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Enhancing A Mobile and Personalized Learning Platform Through Facial Analytics and Interactive Quizzes

Mimansha Gupta[6], *Vincent Tam*[7] *and Edmund Y. Lam*[8]

Abstract

Learning analytics techniques to capture learners' real-time responses can be computationally intensive for mobile devices. Yet with the diversity of many online educational videos such as the Ted Talks, YouTube or other open educational resources, the mobile learning platform intrinsically presents an opportunity for learners and instructors to analyze the pace and quality of learning. In a previous work, the PErsonalized Teaching And Learning (PETAL) platform was developed to monitor the learner's progress in viewing educational videos through a carefully designed facial analytics technique to detect learners' attention levels and their proximity to the screen of the mobile device. The PETAL application will alert a learner if (s)he is not paying attention while viewing an educational video. In this work, we propose to further improve the original PETAL by using online and interactive quizzes to more precisely evaluate the learner's level of understanding while viewing the educational videos. The interactive quizzes can be flexibly added by an instructor by modifying a simple configuration file. When a learner gives an incorrect answer to a particular quiz question, (s)he will be requested to revise a specific section of the concerned video. All the data about the learner's progress is uploaded and stored securely on a password-protected cloud platform to guarantee data privacy for future analyzes. There were some initial and positive students' feedback collected from an empirical evaluation of the enhanced PETAL system. Clearly, the enhanced PETAL platform provides many promising directions for future extensions.

Keywords: learning analytics; personalized learning; mobile devices; web cameras; web application.

1. Introduction

Learning is widely being recognised as a product of interaction. These days, educators are spending more and more efforts into designing their learning methodologies and course content to maximize the value of these interactions. Learning analytics has proven to be an attractive field for research aimed to better understand the process of learning and its environments through measurement, collection and analysis of learner's data and context. There are several techniques that have been deployed in the area of learning analysis that require to estimate the learner's real-time responses to course material or live presentations. However, these are too computationally intensive, and therefore, infeasible for execution on any mobile device (Dinh, Lee, Niyato & Wang, 2011) with limited computational power and storage. These days, with extensive use of mobile devices to watch videos for self-study by a large number of learners, efficient learning analytics methods (Chatti, Dyckhoff, Schroeder & Thüs, 2012;

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Monroy, Rangel, Bell & Whitaker, 2015; Zhou, Han, Yang & Cheng, 2014) can be deployed for preliminary analysis to provide instant feedback to the learner as well make use of web services to do further analysis on the data that has been captured. This could not only deeper understanding of self-study to the learner but also provide thorough reports to course instructors to review overall performance of the whole class and assess quality of study material made by the instructor. This will likely bring in many new pedagogical impacts to the various aspects of teaching, learning, assessments and evaluations of students anytime and anywhere. Consider an example scenario of real-life applications where a primary school teacher in Sciences may ask a group of Grade 5 students to view a video of what was taught in class which introduces some basic concepts of the human respiratory system. While watching the video for self-study, after a sub-topic is completed, each individual student will need to answer a simple quiz consisting of multiple-choice questions on his/her mobile device on which the efficient learning analytics algorithm will quickly generate an initial feedback report to each learner. The quiz questions and timing can be customized by the teacher to help strengthen concepts learnt by the students. After the quizzes have been attempted by all students, the teacher can still receive a more detailed students' progress report sent by the cloud server, reviewing that most of the class has some difficulty in understanding the functionality of lungs for which (s)he may revise the relevant concept in the next lesson. With the portability of mobile devices, learners can review their study material in a way that allows interaction between him/her and the teacher and even other peers.

Besides learning analytics, mobile and sensing technologies have seen a large increase in usage with more and more functionalities being added to them. The usage of mobile devices, smartphones and tablets proliferates in all walks of life. Children of all ages find themselves attracted to these devices and in most households, spend a large amount of time with them. Given the frequent use of technology, especially in the classroom, we find an ever pressing problem: e-Learning (Cantoni, Cellario & Porta, 2004) rarely ever tailors itself to each individual child and gives no indication of the quality of self-study, thereby making it difficult to determine each individual's true grasping or understanding of the taught material. However, at the same time, we find that Computational Intelligence (Jang, 1993), specifically the facial feature detection and recognition techniques (Hennessey, Noureddin & Lawrence, 2006; Ioannou, Caridakis, Karpouzis, & Kollias, 2007), is advancing very rapidly. To tackle these problems and suggest improvements to learners and instructors to improve their self-study, we hereby propose a possible solution to the challenging problem of catering to an individual learner's needs.

To respond to the above problem of evaluating a learner's real-time responses and indicate accurate progress in self-study done through watching educational videos, we tend to look at large eLearning systems with high computational power. However, these fail when the learner is in a remote environment, outside of traditional classrooms. Therefore, in this paper, we explore the applications of the Android programming libraries and the Open Source Computer Vision (OpenCV) software (The OpenCV Development Team, 2014) to develop the PErsonalized Teaching And Learning (PETAL) e-Learning platform (Liu, Tam, Tse, Lam & Tam, 2014) that detects learners' levels of attentiveness and the proximity of their eyes to mobile devices and alert learners when they identified to be distracted, zoning-out, sleeping or too close to the display of the device playing the streaming video clips for personalized learning or self-study through the PETAL e-Learning platform.

Basically, PETAL integrates front-facing cameras to act as image sensors, which are present on a majority of tablets and smartphones currently in the market. Using a simple, yet efficient tracking algorithm the PETAL application continuously monitors and analyzes learners' responses to the video being streamed directly to the app by capturing facial orientation and eye movements thereby providing a truly personalized learning experience to nurture the academic development of learners while protecting their eyesight. It tracks the learner's responses using the front camera present on most of the smart mobile devices by capturing video at 30 frames per second in response to the educational video that the learner is watching as a means of self-learning. PETAL has several applications in the field of learning analytics and also e-Learning as it provides access to learner in his/her self-study environment and opens doors to facilitate interaction between instructors, other peers and further processing of this data using cloud technology. The application has several functionalities such as calibration of learner's position in front of the device, allowing a user to select a video to watch from the videos present locally in the user's device and playing the video in a custom media player. The application will alert the user if he/she is too close to the screen, distracted or sleepy which watching the video and also replays the part which the user may have missed.

The purpose of this work is to extend this functionality and add new features to make the mobile learning application more holistic and facilitate interactions between an instructor and the students.
It has been observed that leaners while watching educational videos often get distracted or do not pay attention and do not go back to the point in the video that they missed. The current version of Petal addresses this issue. However, there has been no interaction between the instructor and the learner. To make sure a learner has understood the concept and has gained the ability to apply it, it is necessary to have some checkpoints or quizzes. Feedback collected from students in February 2016 showed a positive trend with most of them in favour of using PETAL as a mode of self-study outside the classroom. They agreed that the app would provide an excellent way to track their attention levels and test their knowledge. The app introduces a mode for teachers where teachers can set quiz questions and view performance of the class.

This paper is organized as follows. Section 2 reviews the preliminary background and related work on facial feature detection techniques and relevant details about the platform. Section 3 discusses the system design and features of the enhanced PETAL platform. Specific issues about the prototype and its implementation as well as evaluation results are covered in Section 4. Section 5 summarizes the work and sheds light on future work and plans.

2. Preliminaries

This section considers some preliminary work that will facilitate our subsequent discussion. It firstly reviews some previous work on visual computing and natural interaction analysis for e-learning systems. Later, we will consider an earlier work utilizing facial recognition techniques to analyze the learners' head orientations and attention spans in viewing course materials such as the lecture notes on desktop computers. Here, it is worth noting that the facial recognition algorithm employed by PETAL platform is targeted to run both efficiently and effectively on mobile devices such as Android tablets, thus a more challenging task with the very limited computational resources and web cameras of relatively lower resolutions available on the tablet PCs. However, through the mobile applications of our PETAL system, the learners' responses can now be quickly analyzed anytime and anywhere. In addition, the real-time images captured for any individual learner can also be simultaneously sent to the cloud server of our PETAL system to run more sophisticated image processing algorithms for a thorough analysis of the learner's responses.

2.1 Natural Interaction Analysis for e-learning Systems

In (Cantoni, Cellario & Porta, 2004), *Cantoni et. al.* gives a precise overview on the future e-learning systems, from both technology- and user-centric perspectives. Especially, the visual component of the e-learning experience is emphasized as a significant feature for effective content development and delivery. Besides, the adoption of new interaction paradigms based on advanced multi-dimensional interfaces (including *1D/2D/3D/nD* interaction metaphors) and perceptive interfaces (that are capable of acquiring explicit and implicit information about learners and their environment to allow the e-learning systems to "see", "hear", etc.) is presented as a promising direction towards more natural and effective learning experiences.

2.2 A Facial Recognition Method for Analysis of Learners' Responses

Conventionally, many e-learning systems utilize user feedback or profiles, and also try to collect such information based on questionnaires, thus likely resulting in incomplete answers or deliberately misleading input. In (Asteriadis, Tzouveli, Karpouzis & Kollias, 2008), *Asteriadis et. al.* present a specific facial recognition method for the analysis of learners' responses in order to compile feedbacks related to the behavioural states of the learners (e.g. their levels of interests) in the context of reading an electronic document. This is achieved using a non-intrusive scheme through employing a simple web camera installed on a desktop/notebook computer to detect and track the head, eye and hand movements (Hennessey, Noureddin & Lawrence, 2006) and provides an estimation of the level of interest and engagement of each individual learner with the use of a neuro-fuzzy network (Jang, 1993). Experiments show that the proposed e-learning system can detect reading- and attention-related user states very effectively in a testing environment where children's reading performance is tracked.

3. System Features of Enhanced PETAL Platform

Figure 1 shows the design diagram of the activity sequence involved for the enhanced PETAL platform on Android devices. A thorough understanding of the Android life-cycle of activities, fragments, dialog fragments, and the *OpenCV* face detection methods enable us to execute timely notifications and quizzes in the PETAL system. The camera preview screen is hidden from the user while maintaining the communication between face detection data and the video player. When the camera detects an emotion, an emotion variable is set to a specific integer value to be shared with the video player. This mechanism allows us to track and analyze students' responses to educational videos, therefore enabling the PETAL system to pause the video and alert the user as necessary.

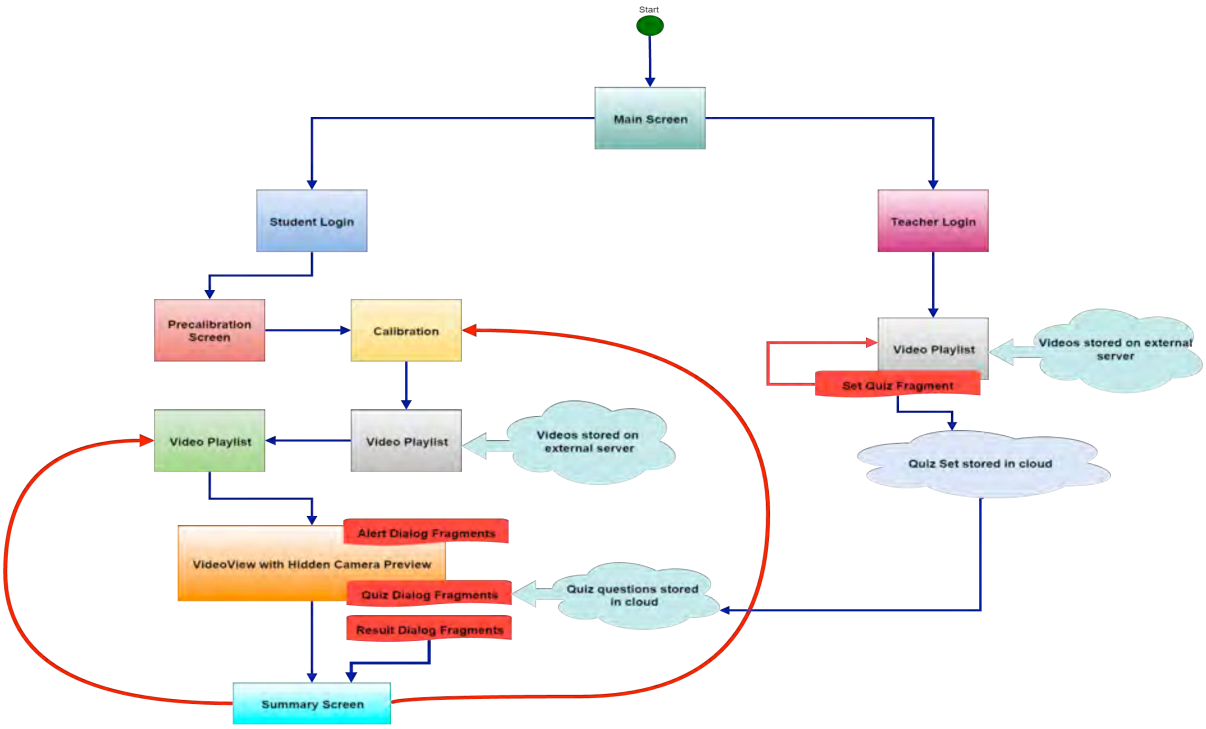

Figure 1. System Diagram showing the Activity Sequence of the PETAL e-Learning Android App

The application tracks the user's eye movements and records times the user was distracted/zoning out/sleepy as well as parts of the video the user chose to replay and indicates these times to the user at the end of the video. If any quizzes have been set to be played during the course of the video, the video is paused, the quizzes are displayed. Once the student answers all questions, result of the quiz is displayed along with suggestions as to which topics the student needs to revise more to truly personalize the student's self-study session and actively interact with the student/user.

To facilitate interactions between learners and instructors, the android application has a Teacher mode. Here, the teacher can set quiz questions and correct answers for educational videos, the exact timestamp they are supposed to appear at as well as the topic each question is related to. These quizzes are stored on a secure database in the cloud and appear to a student only at the timestamp specified when watching the video.

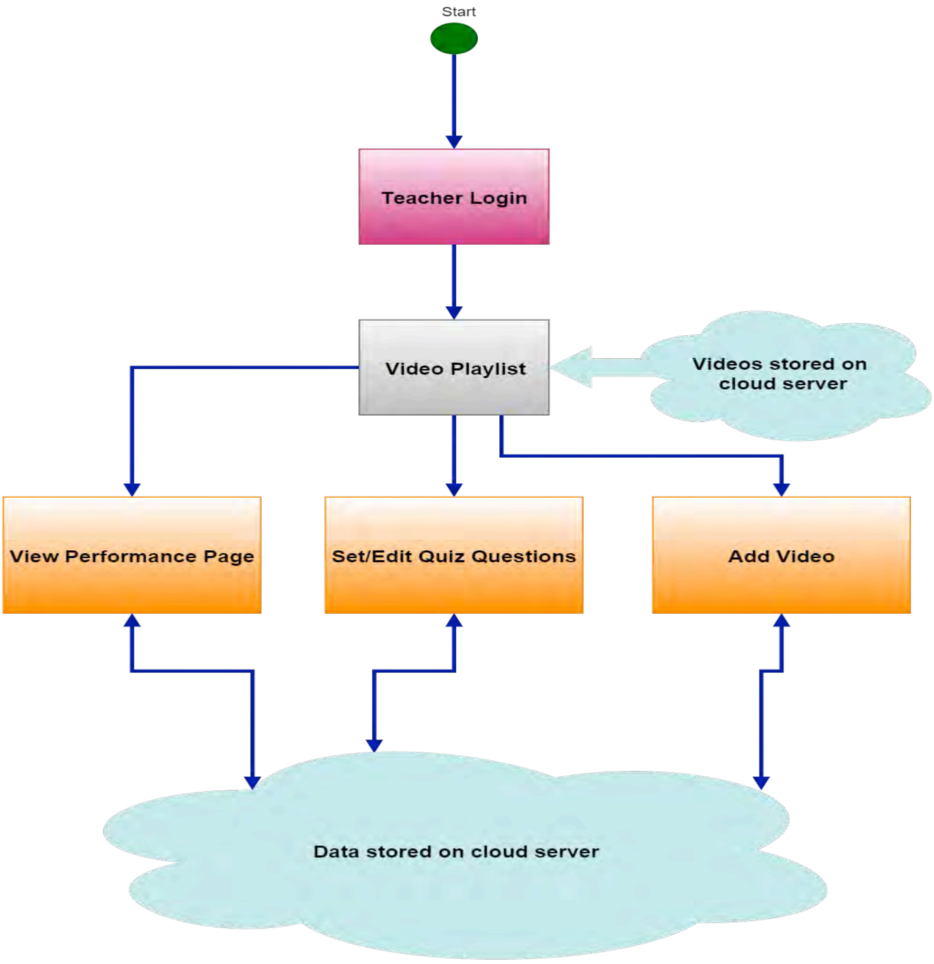

Figure 2. System Diagram showing the Action Sequence of the PETAL supporting Web Application

The teacher can also log into a web application to set questions and view performance of the learners in the quizzes, with the identity of learners hidden, in the form of graphs to identify trends in class performance, identify topics where students were found to be struggling the most to make improvements in teaching material. New videos can also be added through the web application and quiz questions can be added/edited. The web application acts as a management or support application for the teacher to manage and view data well. Figure 2 displays the action sequence diagram of the key supporting web application of PETAL platform.

4. An Empirical Evaluation of Prototype Implementation

To demonstrate the feasibility of the proposed e-learning platform, a prototype of the PETAL Android application was carefully developed on the latest Android system (Version 6.0.1) with the *OpenCV* library (Version 2.4.9) and thoroughly tested. Figure 3 gives the different diagrams showing the pupil detection and its use to determine the learners' distraction in various scenarios with a previous implementation of our PETAL system. There were some initial and positive students' feedbacks collected on our initial prototype and reported by a voluntary student group in HKU. For detail, refer to (Sabih, 2013). Figure 4 shows the two diagrams of calibration and pupil detection of our enhanced PETAL platform to estimate the level of attentiveness and the proximity of the concerned learner to an Android tablet while viewing an educational video with the enhanced version of the PETAL platform.

In a recent empirical evaluation, a small group of 15 Engineering students mostly in their second or third year of studies in the University of Hong Kong were asked to try out the enhanced PETAL system integrated with the interactive quiz function and then responded to a simple questionnaire consisted of 8 questions. These questions were targeted to collect the students' feedback mainly on the effectiveness of the enhanced PETAL system in facilitating their mobile or online learning. Out of the 15 respondents, 9 students (i.e. *60%*) were satisfied with the user interface and features of the enhanced PETAL application. Besides, 11 (around *73%*) out of the 15 students agreed that the enhanced PETAL system is easy-to-use and also effective for self-learning through watching the educational videos. A more detailed evaluation and analysis possibly on a larger number of students will be carefully conducted in primary schools to record response of young learners with respect to the application.

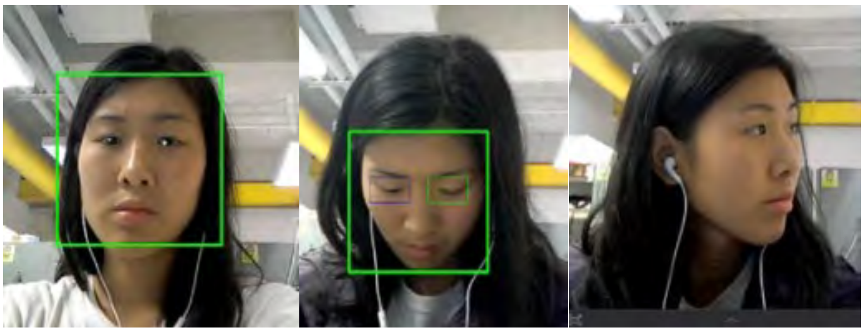

Figure 3. Diagrams Showing the Calibration, Pupil Detection and Its Use to Estimate the Learner's Distraction with a Previous Version of our PETAL system

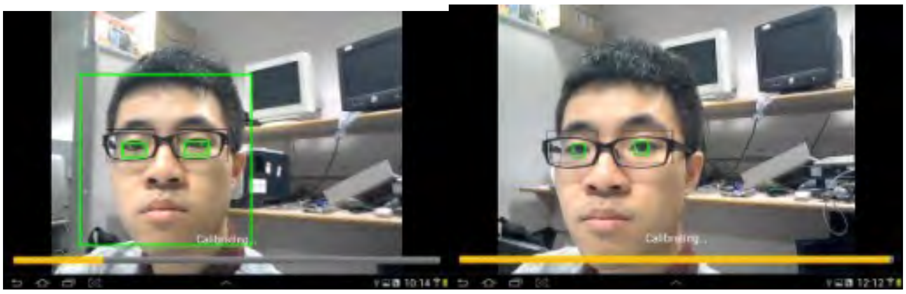

Figure 4. Diagrams Showing the Calibration and Pupil Detection of Enhanced PETAL System to More Precisely Estimate the Learner's Distraction

5. Concluding Remarks

With advancements in mobile and cloud technologies, the reduced costs of mobile devices and cloud computing services and their increased accessibility, the widespread uses of these technologies have been observed in mobile learning environments. In this paper, we have carefully considered an effective enhancement to the original framework of the PETAL e-learning system so as to build an interactive video player application fully integrated with a sophisticated facial analytics technique for detecting eye movement and head orientation, and also an interactive quiz facility to evaluate on the level of learners' understanding. Specifically, we aim to enhance our previous prototypes of the PETAL application to facilitate more effective interactions with the instructors' flexibly added quiz questions and more importantly the uploading of the valuable learners' progress and log data onto the cloud platform for a thorough analysis. Clearly, the enhanced PETAL mobile application together with the new supporting web functions provides a holistic mobile learning platform.

There are many possible directions for future investigations. A possible direction is extending the support to other operating system platforms such as the iOS and desktop environments to cover a wider range of end users. Through widening the user base, the collected data and analysis results can be more representative and thorough. Furthermore, future enhancements in both hardware, such as an increase in the rate of image frames being captured by the underlying web camera, and software with more updated versions of the *OpenCV* library or more accurate facial analytics methods should be carefully considered. On top of it, future investigations in further cascade training and enhancement in the pose detection algorithms may help to promote the capability of the PETAL system to detect other relevant types of student responses like confusion or frustration are worth exploring. Last but not least, it is both interesting and useful to use Machine Learning algorithms to predict class performance based on certain learning models and the collected learners' data, and possibly facilitating the concerned instructor in gaining a deeper understanding on the learning abilities of the whole class, especially on some difficult topics.

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References

Asteriadis, S., Tzouveli, P., Karpouzis, K., & Kollias, S. (2008). Estimation of behavioral user state based on eye gaze and head pose—application in an e-learning environment. Multimed Tools Appl Multimedia Tools and Applications, 41(3), 469-493. doi:10.1007/s11042-008-0240-1.

Cantoni, V., Cellario, M., & Porta, M. (2004). Perspectives and challenges in e-learning: Towards natural interaction paradigms. Journal of Visual Languages & Computing, 15(5), 333-345. doi:10.1016/j.jvlc.2003.10.002

Chatti, M. A., Dyckhoff, A. L., Schroeder, U., & Thüs, H. (2012). A reference model for learning analytics. International Journal of Technology Enhanced Learning IJTEL, 4(5/6), 318. doi:10.1504/ijtel.2012.051815

Dinh, H. T., Lee, C., Niyato, D., & Wang, P. (2011). A survey of mobile cloud computing: Architecture, applications, and approaches. Wireless Communications and Mobile Computing, 13(18), 1587-1611. doi:10.1002/wcm.1203

Hennessey, C., Noureddin, B., & Lawrence, P. (2006). A single camera eye-gaze tracking system with free head motion. Proceedings of the 2006 Symposium on Eye Tracking Research & Applications - ETRA '06. doi:10.1145/1117309.1117349

Ioannou, S., Caridakis, G., Karpouzis, K., & Kollias, S. (2007). Robust Feature Detection for Facial Expression Recognition. EURASIP Journal on Image and Video Processing, 2007, 1-22. doi:10.1155/2007/29081

Jang, J. (1993). ANFIS: Adaptive-network-based fuzzy inference system. IEEE Transactions on Systems, Man, and Cybernetics IEEE Trans. Syst., Man, Cybern., 23(3), 665-685. doi:10.1109/21.256541

Liu, K., Tam, V., Tse, P., Lam, E. Y., & Tam, V. (2014). Developing the PETAL e-Learning Platform for Personalized Teaching and Learning. Emerging Issues in Smart Learning Lecture Notes in Educational Technology, 119-122. doi:10.1007/978-3-662-44188-6_17

Monroy, C., Rangel, V. S., Bell, E. R., & Whitaker, R. (2015). A learning analytics approach to characterize and analyze inquiry-based pedagogical processes. Proceedings of the Fifth International Conference on Learning Analytics And Knowledge - LAK '15. doi:10.1145/2723576.2723658

Sabih, T. (2013). PETAL: Learning the Android Way, The HKU Journal of Technology (TecHKU), URL at: http://www.engineering.hku.hk/tecHKU/2013/11/11/petal/, last visited in November, 2013.

The OpenCV Development Team, (2014). The OpenCV, URL at: http:// http://opencv.org/, last visited in March, 2014.

Zhou, Q., Han, X., Yang, J., & Cheng, J. (2014). Design and Implementation of Learning Analytics System for Teachers and Learners Based on the Specified LMS. 2014 International Conference of Educational Innovation through Technology. doi:10.1109/eitt.2014.21