Personalized Mobile Learning System via Smart Glasses

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Abstract. This work proposes a personalized mobile learning system using smart glasses which include outward and inward facing cameras. By using the outward facing camera, the proposed system recognizes the QR code, and then discovers the front view of a wearer. Additionally, our system employs an inward facing camera to capture eye images, find out the centers of irises, and then derive visual focal points. According to the exhibit of high interest, the audiovisual clips associated with the baseball background knowledge and stories were designed for learners visiting the baseball museum. The experimental results reveal that the proposed system can achieve a view angel deviation below 3.20°, and identify the 13.5 cm × 13.5 cm QR code at a distance of 2.3 m and a view angle of 40°. Therefore, the personalized mobile learning system proposed herein effectively provides learners with attention tracking, interest cultivation, and immersive engagement.

Keywords: Mobile learning · Smart glasses · Eye tracking Pattern recognition · Visual focal point · QR code

1 Introduction

With the progress of science and technology, learning is not confined to the classroom. Wearing a portable device in outdoor learning has become a new trend. However, how wearable devices attract learners' attention and evoke their interest needs to be well addressed. There are many outdoor learning situations, like zoo tour, museum visit and so on, in which most of the guidance ways adopt voice navigation instead of narrators. Since most people prefer a visual or audiovisual way to catch knowledge, our work employs smart glasses to provide the audiovisual guide based on wearer's visual focal points, and thus to enhance the learning effect.

In outdoor learning, because the theme cannot take into account all learners' preferences, some of the learners may miss their subjects of interest in the learning process. At present, many outdoor learning venues, such as museums and art museums, have a number of buttons or QR codes for audio or audiovisual clips, requiring visitors to take the initiative to push the button or scan the QR code for further illustrations of

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the exhibit. The QR code identification generally goes through the pattern detection, decoding, and information extraction steps to catch the code message. Currently, there are many online resources that can provide QR code decoding [4, 5]. However, it may be inconvenient for visitors to find out the button or QR code, resulting in missing further information acquirement. If smart glasses with an outward facing camera can help on automatically detecting the QR codes, a visitor can receive further information easily and interact with the exhibits in a more efficient way.

Usually, a learner takes long time to look at things that are of interest, so that eye tracking is the most direct and effective way to determine whether it is a matter of interest. Pande *et al*. employed the visual tracking technique to perceive eye movements of students who were stimulated by symbolic and graphic patterns in order to understand their learning processes [1]. Yang *et al*. tracked eye movements of viewers to know their learning statuses during slide presentations where the slides included the pictures and text [2]. By introducing media from internet in the conventional teaching, Zhou *et al*. gathered eye movement information of a leaner, analyzed it to understand the learning situation, and then figured out an approach to improve the learning efficiency of this mixed teaching scenario [3]. Therefore, learning points of interest from visual focal points of most people can be referred to design effective teaching materials. In particular, when you put on smart glasses with inward facing cameras, like Tobbi smart glasses with four cameras on the frame to fulfill eye tracking, the visual focal point can be estimated to interpret the eye movement behavior for understanding interactions and situations of learning.

In order to achieve the abovementioned functions, this study proposes a personalized mobile learning system using smart glasses which have outward and inward facing cameras. Accompanied with a tablet or a smart phone to support auxiliary signal analysis, identification, and learning assessment, the proposed smart glasses can provide a wearer with multidimensional learning. The outward facing camera detects the QR code which is decoded, and then linked to the corresponding information. The inward facing camera in the proposed smart glasses captures eye images which are processed to obtain the central points of irises for eye tracking. Additionally, the central points are projected outwardly to discover visual fixation and gaze time, to deduce the points of interest. From a professional education perspective, the questionnaires and experiments were designed, and conducted by 30 subjects to attain the exhibit areas of interest from the majority. According to the areas of interest, further interaction materials such as images, texts, and films were adequately implemented to evoke learners' interests. With QR code recognition and eye tracking, the proposed system can take the initiative to present the learning materials to a visitor according to his or her visual focal point, and thus effectively enhances the learning effect.

2 Personalized Mobile Learning System

In this work, the experimental scenario is museum visit where visitors wear the proposed smart glasses with tablets or smart phones. The personalized mobile learning system is developed to provide intimate interactions according to visitor's interests from his or her visual focal points. Accordingly, the front view of a visitor at a specific position needs to be well known. Based on the front scene, the visual focal point may reveal the exhibit of interest. Meanwhile, the corresponding messages are provided to the visitor for enhancing the understanding of the exhibit. To realize this demand, the proposed smart glasses include an outward facing camera for QR code detection, an inward facing camera for eye tracking, and a display screen for information conveyance. The commercial smart glasses, SiME, from ChipSiP Technology Corp. are utilized and modified where the original outward facing camera is replaced by an inward facing camera, and the outward facing camera module from C920r USB webcam, Logitech, is mounted on the front frame of smart glasses, as shown in Fig. 1. Particularly, the 3D housing enclosing the outward facing camera module was implemented as well.

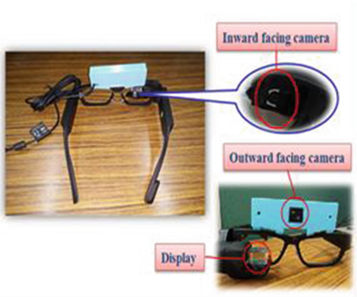


Fig. 1. Proposed smart glasses.

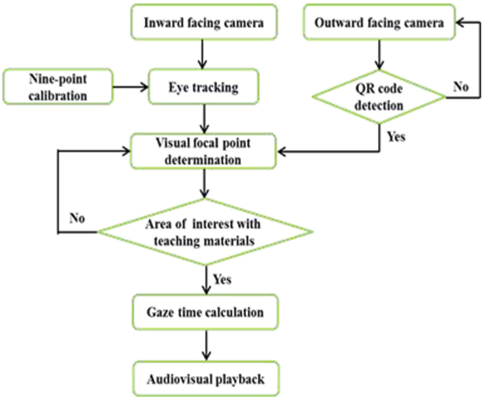


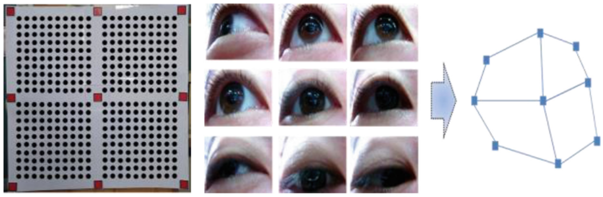
Fig. 2. Operational flow of the proposed system.

The proposed system includes three parts: (1) determination of front views from the QR code detection, (2) determination of visual focal points from eye tracking, and (3) teaching material designs from the professional survey associated with exhibits of interest. The QR code detection is to find out the front view of a subject wearing smart glasses with an outward facing camera. Before eye tracking using an inward facing camera, the 9-point calibration is performed to catch the eye movement characteristics, and to amend the wearing differentiation from each subject. The iris region of a wearer's eye is identified, and then used to determine its central point which is projected to the fixation point of the front scene. The proposed system takes the initiative to capture front scenes, and eye images for QR code detection, and eye tracking, respectively. When a subject watches the exhibit of which QR code is found, his or her visual focal point is derived at the same time. Once the visual focal point remains unchanged for 300 ms [6], the corresponding teaching material is displayed on the screen for the friendly interaction with the subject to improve learning outcomes. The operational flow of the proposed system is depicted in Fig. 2.

2.1 Determination of Front Views

The front view of a learner is consistent with the outward facing camera. In this work, the QR code pattern is used due to its clear and strict structure, and attached to the spot close to the exhibit, as displayed in Fig. 3. The proposed system actively and continuously detects the QR code pattern of the captured images from the outward facing camera. The QR code goes through binarization and morphology for pre-processing, convolution for positioning, and neural network for pattern recognition [7]. Once this code is successfully decoded, the front view of a subject at a specific position is identified based on the previously established database.

Fig. 3. Exhibit with a QR code.



(a) (b)

Fig. 4. Calibration points associated with iris positions. (a) Calibration pattern. (b) Topology graph of eye movements (Color figure online)

2.2 Determination of Visual Focal Points

In order to precisely calculate the fixation point of eyes, the screen with 9 red spots and 400 small black spots distributed at a square of 50 cm × 50 cm is designed, and partitioned into four quadrants for calibration, as shown in Fig. 4(a). In this screen, each quadrant has 100 black spots where the neighboring ones have a distance of 2 cm. Figure 4(b) depicts the topological graph of eye movements of a subject who stands 1.5 m from the screen, and watches these nine red spots. This graph is not a square because the moving distance of an iris is not uniform at each side. Additionally, an inward facing camera which is not located at the central point of an eye has a shooting angle deviation. Nevertheless, the relative positions of nine red spots are correct, so that each group of 100 black spots can infer the corresponding quadrant. After calibration, four areas of left top, left bottom, right top and right bottom corresponding to iris positions are derived to accurately determine visual focal points of each subject.

It is a straightforward way to fulfill eye tracking using a camera which captures eye images. These eye images are analyzed to obtain an eye movement track. This study modifies, and simplifies the methods proposed by Zhao *et al.* [8] and Cuong *et al.* [9] with consideration of computation power of the proposed smart glasses. Figure 5 displays the computation flow of the proposed eye tracking method for determining the visual focal point. The inward facing camera of the proposed smart glasses takes an eye color image which is converted to a gray-level image based on the luminance. This gray-level image can be partitioned into two parts: bright one for skin and sclera, and dark one for pupil, iris and eyelashes. Accordingly, the gray-level histogram is built, and characterized by two Gaussian mixture models which can determine an adequate threshold. This threshold binarizes the gray-level image to yield a binary image which goes through the Gaussian blur and morphological operations for image smoothing and noise reduction, respectively. After the abovementioned processes, a complete eye contour in the binary image can be attained. The X-axis coordinates of dark points in the binary image are searched to find out leftmost and rightmost ones which have neighboring pixels with the interleaved black and white. These leftmost and rightmost dark points are viewed as eye corners. A circle is drawn based on the diameter from left to right eye corners. The maximum square inside this circle is the Region Of Interest (ROI). At the same time, the Hough transform is performed in the binary image to get many circle curves of which central points and radiuses are derived. If central points of circles are not inside the ROI, and radiuses are larger than a half of distance between left and right eye corners, these circles are not considered. Afterwards, the relative large circle is taken as the iris of which central point is used to project a visual focal point. This visual focal point may indicate the portion or whole of the exhibit of interest.

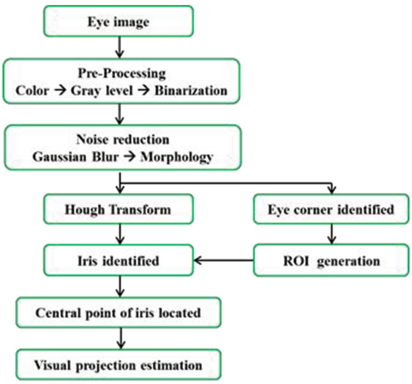


Fig. 5. Proposed eye tracking method.

Fig. 6 Photo of an exhibition area with 54 portions.

2.3 Teaching Material Design from Areas of Interest

In this study, the baseball museum of National Chung Cheng University is the experimental field. Initially, the visual focal points of learners were analyzed by means of the questionnaire to catch the hotspots from the majority. Based on the eye-mind assumptions [10], the eye gaze direction reveals the area of cognitive and attentive processes. Accordingly, the hotspot is what the learner is interested in, and pays more attention to. First, the photos associated with 16 exhibition areas were taken in the questionnaire where each photo is partitioned into many small portions. Second, 30 subjects visited the museum, stood in front of each exhibition area, selected top 20 portions of interest, and marked them on the corresponding photo in the questionnaire. Finally, after compiling the results from 30 subjects, the three portions with the highest scores in each exhibition area are determined for us to design the relevant teaching materials. Figure 6 shows the photo of an exhibition area, which is partitioned into 54 portions.

In order to design the materials that most people are interested in, this study categorizes the exhibition into four main themes: history, people, ball sets and sport care, through the field tour of the museum exhibition, and interviews with senior tour guides and experts. Additionally, learners filled in the demand questionnaire of which data were analyzed to understand the learners' suggestions and interactive preferences associated with learning topics. The results show that history and character themes need to add the video and picture supplement, ball theme is to increase the 3D graphic models and the corresponding films, and sport care theme demands the advices from experts and doctors. Based on the above results, this study has accomplished various teaching materials according to different topics of four themes. Therefore, it is hoped that learners can resonate with these teaching materials to obtain effective learning.

3 Experimental Results

In this work, the baseball museum of National Chung Cheng University is the experimental field in which subjects wore the proposed smart glasses and carried tablets for museum visits. Before going to see the exhibits, each subject followed the guideline, and watched a nine-point calibration screen to amend wearing deviations, and to align the eye position with the eye focal point. The outward facing camera of the proposed smart glasses is actively and continuously to detect the QR code based on which the front scene of a subject is effectively discovered. When the gaze time is larger than 300 ms [6], the teaching material related to the exhibit is played at the screen of the proposed smart glasses. In the following, we explore the accuracy of visual focal points, QR code detection rate, and learning effect using the proposed smart glasses.

When performing the calibration, the participant stood at a distance of 1.5 m from the 50 cm $\times$ 50 cm calibration screen. All subjects watched nine red spots one by one, and then correlated these red spots with their eye positions. Table 1 lists the eye angle deviations from 10 participants where the average eye angle deviation is 3.20°. This average value exhibits that the proposed eye tracking method for determining visual focal points is very promising.

Table 1. Eye angle deviations from 10 subjects.

Subject_1	3.45
Subject_2	2.79
Subject_3	3.69
Subject_4	3.23
Subject_5	2.96
Subject_6	2.68
Subject_7	3.56
Subject_8	3.07
Subject_9	3.66
Subject_10	2.94
Average	3.203

Table 2. Acceptable view angles and distances of two QR code patterns.

Pattern	View angles (deg)	Distances (cm)
10 cm * 10 cm	0	170
	30	140
	45	100
13.5 cm * 13.5 cm	0	280
	30	250
	40	230

To order to effectively perceive the QR code pattern at a reasonable view angle and a fair distance, two versions of QR code patterns are designed, and explored. Figure 7 shows the topologies of these two patterns with sizes of 10 cm × 10 cm, and 13.5 cm × 13.5 cm. Table 2 lists the acceptable view angles and distances of these two patterns which are correctly decoded. The experimental results illustrate that the 13.5 cm × 13.5 cm pattern has an additional rectangular shape at the right bottom, resulting in outstanding performance.

(a) (b)

Fig. 7. Two QR code patterns (a) 10 cm × 10 cm pattern. (b) 13.5 cm × 13.5 cm pattern.

In addition to narrators, the audiovisual playback screens and handheld audio devices helping on tour guiding can effectively reduce manpower. Such screens and devices have been widely adopted in the majority of museums. However, there exist some shortcomings at fixed-position audiovisual playback screens, and handheld audio devices. This is because the time of each visitor arriving at a specific exhibition area is not consistent. The fixed-position audiovisual playback cannot match the progress of each visitor, easily resulting in learning incompletely or inattentively. Additionally, the open play may make voices of adjacent booths interfere with each other. Although a handheld audio device can provide audio playback to each visitor individually to avoid inconsistent arrival time, the visitor may feel uncomfortable owing to the headset covering the entire ear or wearing in the ear canal. Particularly, the visitor may not response to an emergency immediately owing the headset isolating external sounds to some extent. However, learning messages are addressed only by voice, which may not meet the demands of various learning enthusiasts. Therefore, this work employs smart glasses as a tour guide in a museum to increase the immersive engagement, to enrich the learning content, and to achieve personalized learning. Museum curators and educators can compile and analyze visual focal points and positions of visitors from the proposed smart glasses to attain the exhibits of interest, visit tracks, and learning situations. Based on the exhibits of high interest, we created the corresponding teaching materials to guide learners to watch these exhibits, and to increase the awareness of key knowledge. Notably, the proposed mobile learning system can effectively grasp visual focus points of a learner, proactively recommend learning materials, and assess the learning outcomes. As compared to the conventional handheld audio devices, the proposed smart glasses can superiorly convey the concept of the exhibit, attract user's attention, and thus enhance learning effect.

4 Conclusion

In this work, the personalized mobile learning system using smart glasses has been successfully developed. The proposed smart glasses have an outward facing camera for front scene determination, an inward facing camera for visual focal point determination, and a display screen for information conveyance. The front scene of a subject is perceived by detecting the QR code which is attached to a spot close to the exhibit. The visual focal point of a subject is determined by the proposed eye tracking method that identifies the central point of the iris, projecting outwardly to find the hotspot. Before eye tracking, the nine-point calibration is fulfilled to amend subject deviations. The baseball museum of National Chung Cheng University is the experimental field. Initially, the visual focal points of subjects were analyzed by means of the questionnaire to catch the hotspots from the majority. Afterwards, the teaching materials associated with the exhibit of high interest were designed. The experimental results reveal that the proposed system can have a view angle deviation smaller than 3.20°, and recognize the 13.5 cm × 13.5 cm QR code at a distance of 2.3 m with a view angle up to 40°. Compared to the handheld audio devices, the proposed smart glasses show outstanding performance on conveying the knowledge of the exhibit, and increasing user's immersion.

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