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Attention Analysis in E-Learning Environment using a Simple Web Camera

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***Abstract*— A real-time non-intrusive attention tracking system using a simple web camera is proposed in this paper. This system is scale and rotation invariant and tolerant to blink related false attention state classifications. Attention states of the students are classified into three: attentive, sleepy and disappeared. A simple geometric model for eye corners detection is proposed. Active and passive attention tracking experiments are conducted with a 54 minutes video lecture as the e-learning session content. Experimental results show that the proposed system clearly discriminates the attention states of the student participated in the E-learning session. The execution time of the proposed algorithm is 10 milliseconds per image frame. The proposed system is highly suitable for real-time applications.**

***Keywords*— E-learning, Attention Analysis, Eye Tracking, Eye corner detection, Attention States**

I. INTRODUCTION

E-learning comprises all forms of electronically supported learning and teaching. E-learning is essentially the computer and network-enabled transfer of skills and knowledge. E-Learning can be self-paced or instructor-led and includes media in the form of text, image, animation, streaming video and audio. Today, E-learning aims to be strongly student centered, in order to provide a personalized learning experience. Its principal objectives are then not only to foster successful learning but also to involve students in the learning process and maximize their interest.

A teacher easily captures the attention state of students and adapts lessons accordingly, in order to maximize their interest and participation. In the traditional E-Learning system, the timely information about attentiveness of a student to an ongoing E-Learning class is missing. In order to provide a quality learning experience, an E-learning system should perform attention analysis on the students. The proposed attention tracking system is to narrow the gap between an E-Learning environment and a real-world class room. The proposed system tracks the attentiveness and classifies the attention states as: attentive, sleepy and disappeared.

II. LITERATURE SURVEY

In [3], the authors present WiSe, a system that detects the attention of a student using posture analysis, keyboard and mouse input analysis and CPU concurrent tasks analysis. In [2], an Interest Meter, a system to measure user's interest and thus use it to conduct video summarization is introduced. Eye movement, blink, head motion and facial expression are considered in Interest Meter design for estimating attention state of the user. In the context of intelligent vehicular systems, drowsy driver detection is an active area of research in the last decade. A comprehensive survey of driver inattention monitoring is given in [1].

III. PROPOSED METHOD

Flow diagram of the proposed attention tracking system is shown in figure 1. From the live video stream, face region is detected using Haar Cascade Classifier [4]. The face region is divided into left and right halves. The left and right eye locations are detected using Haar Cascade Classifier trained for eye detection. Let (x_L,y_L) be the left eye location and (x_R,y_R) the right eye location, the inter-eye distance D and the roll angle θ are calculated using equations 1 and 2.

$$D = \sqrt{(x_L - x_R)^2 + (y_L - y_R)^2} \tag{1}$$

$$\theta = \tan^{-1}\left(\frac{y_L - y_R}{x_L - x_R}\right) \tag{2}$$

Empirically we found that, the distance between the inner corner and outer corner of an eye is one-third the inter-eye distance. Thus the inner corner and outer corner locations for the left eye can be found through equations 3 and 4. Once the inner and outer corner points are detected in a frame, the corner points will be tracked in the subsequent frames using Lucas-Kanade tracker. Thereafter the inner and outer corner point detection operations will be performed only when the points are lost in tracking.

$$(x_{LI}, y_{LI}) = \left(x_L + \frac{D}{6} sin\theta \ , y_L + \frac{D}{6} cos\theta\right) \qquad (3)$$

$$(x_{LO}, y_{LO}) = \left(x_L - \frac{D}{6} sin\theta \, , y_L - \frac{D}{6} cos\theta\right) \qquad (4)$$

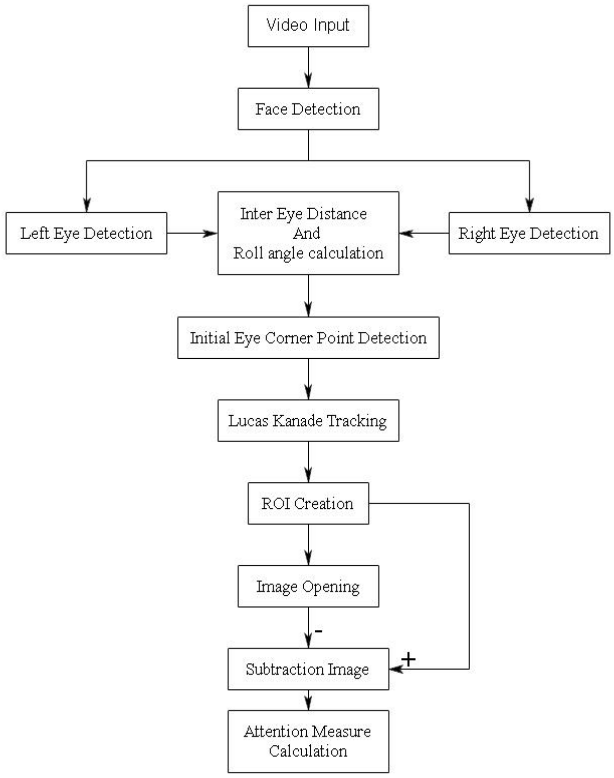

Fig. 1 Flow diagram of the proposed attention tracking system

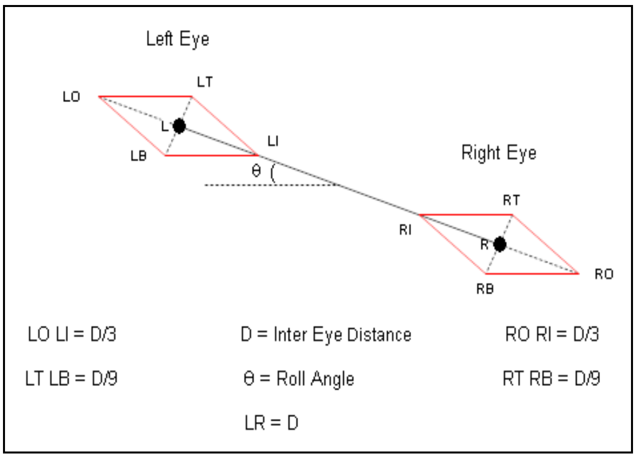

Fig. 2 Geometrical model of the proposed Region of Interest (ROI)

The average height to width ratio of the visible eye-ball region is 1:3. We formed a rhombus as the region of interest (ROI) with the inner corner, outer corner as the 2 vertices and the diagonals intersects at (x_L, y_L).The length of diagonals are *D/3* and *D/9*. The geometrical model of the proposed ROI is shown in figure 2. The vertex locations of the top point (x_{LT},y_{LT}) and the bottom point (x_{LB}, y_{LB}) of the ROI rhombus for the left eye can be obtained using the equations 5 and 6. Using the similar equations the ROI rhombus for the right eye can be obtained. As the ROI rhombus takes into account of the inter-eye distance D and roll angle θ, the proposed attention tracking system is scale invariant and rotation invariant.

$$(x_{LT}, y_{LT}) = \left(x_L - \frac{D}{18} * cos\theta \, , y_L + \frac{D}{18} * sin\theta\right) \qquad (5)$$

$$(x_{LB}, y_{LB}) = \left(x_L + \frac{D}{18} * cos\theta \, , y_L - \frac{D}{18} * sin\theta\right) \qquad (6)$$

The ROI image is morphologically opened to remove the highlights present in the eye due to the computer monitor and other light sources. The morphologically opened image is subtracted from the ROI image. The subtraction operation retains only the highlights present in the eye and removes other features of the eye. In the case of open eye images, highlights will be present after this subtraction operation, whereas, for closed eye images, highlights will not be present. This property is exploited in measuring the attention of the student.

Attention is measured as the average intensity in the ROI region after the subtraction operations. Thus the attention measure (*AM(t)*) at each frame is calculated using equation 7. To avoid false transitions of the attention states due to blinking, a sliding window median operation is performed on *AM(t)* with a window W of size 20 frames. The attention states are classified according to equation 9 by thresholding $AM_{med}(t)$.

$$AM(t) = \frac{\sum_{ROI} Subtracted\ Image}{Number\ of\ Pixels\ in\ ROI} \qquad (7)$$

$$AM_{med}(t) = median\{\textstyle\sum_t^{t-W} AM(t)\} \qquad (8)$$

$$AttentionState(t) = \begin{cases} Attentive, & AM_{med}(t) \geq threshold \\ Sleepy, & AM_{med}(t) < threshold \\ Disappeared, & Face\ Detection\ failure \end{cases} \qquad (9)$$

The proposed attention tracking system is real time, scale and rotation invariant and tolerant to blink related false classifications.

IV. Experimental Setup

In an active attention tracking system, a feedback mechanism is present to notify the user with alert signals when inattentiveness is detected. The attention status and the corresponding bookmarks in the E-learning content will be stored in the database. Passive attention tracking system does not have feedback to the user but the attention status and the corresponding bookmarks in the E-learning content will be stored in the database. The active attention tracking system is suitable for user notification purpose in an E-Learning environment. The passive attention tracking system is suitable for E-Learning course content evaluation purpose.

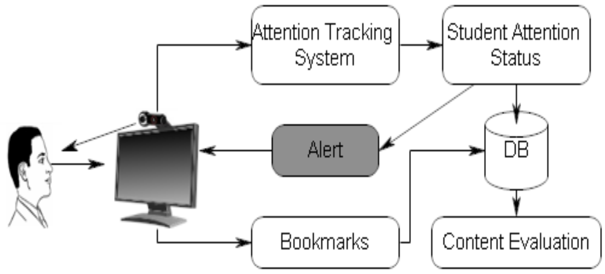

Fig. 3 Experimental setup for Active Attention Tracking

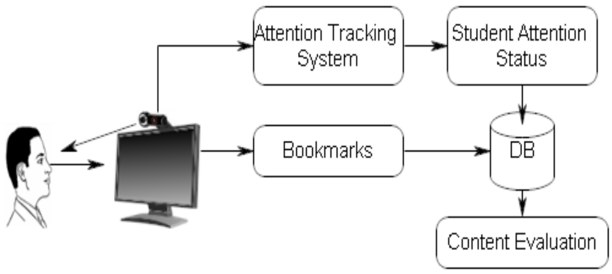

Fig. 4 Experimental setup for Passive Attention Tracking

The E-Learning course content is logically divided and bookmarks are inserted prior to attention tracking. The attention status of the user between each bookmark is analyzed and the course content is evaluated.

V. Experimental Results

For morphological opening we used a square structuring element of size 5X5. We empirically found that the threshold value of 15 is optimal for attention state classification.

(a) (b) (c)

Fig. 5 Eye corner detection results: (a) User sitting close to the computer monitor, (b) User with head tilt, (c) User sitting far away from the computer monitor

NPTel video lecture on introduction to image processing [6] is used as the E-Learning content in our experiments. It's a 54 minute video lecture. We logically divided it and kept 18 bookmarks (One bookmark for each presentation slide). E-learning sessions of 8 Post graduate students are monitored using the proposed attention tracking system.

(a) (b) (c) (d) (e) (f)

Fig. 6 Eye corner detection results: (a) Open eye image, (b) result of Morphological opening of (a), (c) result after subtraction operation, *AM* value is 30.58, (d) Closed eye image, (e) result of Morphological opening of (d), (f) result after subtraction operation, *AM* value is 2.63.

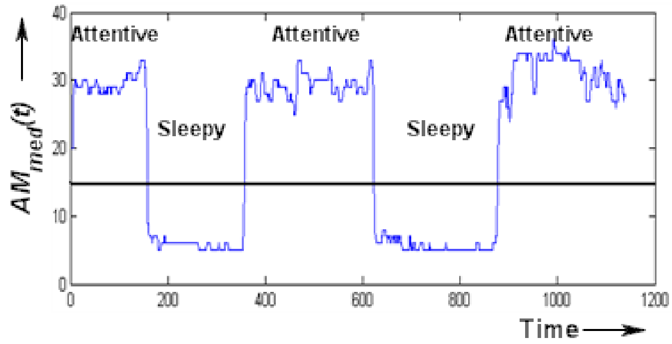

Fig. 7 Plot of attention measure and classification of attention states over one minute duration

We used Logitech Webcam Pro 9000 [5] in our experiments. Video is captured at the resolution of 480X640 and 30FPS. The proposed attention tracking system is prototyped in Matlab and implemented using OpenCV. In OpenCV, the execution time of the proposed algorithm for key frames (including face detection, eye detection and corner detection) is 36 milliseconds and for other frames (which involves Lucas-Kanade tracker) is 10 milliseconds. Thus the proposed attention tracking system is highly suitable for real-time applications.

VI. Conclusions

A real time attention tracking system is proposed in this paper. It narrows the gap between the real classroom scenario and E-learning sessions. The proposed system helps to evaluate the E-learning course content and notifies the student on inattention to the E-learning session. The proposed system can be customized to evaluate the performance of a student, to create user-adaptive course material, to support the student by delivering a summary report on attention profile at the end of an E-Learning session and many more

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