Blink Detection Based on Pixel Fluctuation Ratio of Eye Image

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Abstract: In this paper, an algorithm of real-time eye blink monitoring using ordinary camera is proposed. This algorithm is based on pixel fluctuation ratio (FRP) of eye region image to detect eye blink. Position the eye area according to the facial landmark algorithm and then convert the image to a grayscale image. According to the point detected by the eye region in the grayscale image, the eye region is divided into three segments from the corner of the eye to the end of the eye. Calculate the value of the pixels in each segment, and find the partial image pixel value fluctuation ratio (FRP), and train the selected training samples with the support vector machine (SVM). We tested it on two data sets, and the blink detection algorithm achieved good results on both data sets.

1. Introduction
As an important organ of human face, eyes can reflect many physiological and psychological activities. Eye changes can provide references for many fields. For example, as the core of the system, it can be used in detecting driver fatigue[1][2], Man-Machine interactive system and through the detection blink response human psychology change in the psychology, etc[3]. Human body, mind and emotions can affect their blink frequency[4][5]. Blink recognition can also help disabled people with simple computer operations.

This paper proposes a blink detection algorithm based on pixel fluctuation ratio of eye grayscale image (PFR). This algorithm can locate the eye position through the facial marker position. Then, the image is converted into grayscale image, and the eye region of the grayscale image is divided into three segments from the corner of the eye to the tail of the eye according to the detected points. The pixel value of each segment is taken, the maximum and minimum pixel values of each segment are extracted, and the fluctuation ratio of the pixel value of this part of the image is calculated.

2. PFR Algorithm
In this paper, the algorithm is convert each frame of the video to grayscale image and 6 feature points of the eye region are extracted using facial marker feature points, the eye region is divided into three segments and the maximum value and minimum value of pixels in the three segments are extracted, then the fluctuation ratio of pixel value of each image is calculated[6][7]. By the change of pixel fluctuation ratio of the image, the blink is judged.

2.1. Image Preprocessing
In this paper, ordinary camera is used to collect video data of user's face. The experimental environment should be stable and full of light. During the process of video data collection, the subject sits in front of
video collection equipment, maintains a distance of 0.3~0.5 m from the equipment, faces to the camera and keeps the entire face area within the frame of the camera without any shelter. The algorithm will collect every frame in the video sequence, convert them to grayscale images, use face-recognition to locate the face in the images and recognize key points of the face, including eyes[8][9], nose, mouth and chin (see Figure 1).

![Figure 1. Face recognition key points detection](image)

2.2. Pixel Fluctuation Ratio of Grayscale Image

The grayscale image of the eye region is obtained by image preprocessing. Then the supervised descent method (SDM) is used to mark the eye area with symbols \( L_0, L_5, R_0, R_5 \) (see Figure 2(a)). Connect \( L_0, L_1, L_4, L_5 \) and \( L_0, L_3 \) lines (see Figure 2(b)). Where \( L_A \) and \( L_B \) are respectively the midpoints of \( L_2 \) and \( L_6 \) and \( L_3 \) and \( L_5 \).

![Figure 2. (a)Feature points of the ocular region(b) connects ,  and  where A is the midpoint of  and B is the midpoint of ](image)

For each video frame, the eye markers are fixed. By calculating the pixel values on the straight lines of \( L_0, L_1, L_4, L_5 \) and \( L_0, L_3 \) in the eye region of each video frame, the fluctuation ratio of pixel values (FRP) in this part of the image is calculated. The calculation formula is as follows:

\[
FRP = \frac{P_{\text{max}}}{P_{\text{min}}}
\]

In the formula, \( P_{\text{max}} \) and \( P_{\text{min}} \) represent the maximum pixel value and minimum pixel value in the whole three lines[11].

When the eyes are open, the FRP value is relatively large, while when the eyes are closed, the FRP value is relatively small. As blinking is a dynamic process, we can detect blinking by analyzing the changes of FRP values (see Figure 3). As can be seen from the figure, the FRP curve has obvious wave peak when blinking, while the FRP curve tends to be flat when eyes are open and closed, and there is no obvious fluctuation. Generally, Blinking is done in sync with both eyes. So, video frames with the same changes of FRP values in the left eye and right eye were judged as blinking[12][13].

![Figure 3. FRP wave curves of blinking, open and closed eyes](image)
2.3. Selection of Training Samples and Training Classifier

2.3.1. Open and Closed Eyes Classifier
Since the pixel fluctuation in the eye area is larger when the eyes are open but the FRP value is small when the eyes are closed. When training SVM classifier, video frame with open eyes is marked as positive sample, and video frame with closed eyes is marked as negative sample[14][15].

2.3.2 Blink and Non-blink Classifier
After the first step of classification, video frames with closed eyes can be distinguished. Through experiments, it can be concluded that 8 frames can well describe the blinking process. Therefore, an 8-dimensional feature can be obtained by concatenating the FPR values of the first 3 frames and the next 4 frames which are adjacent to the eye-closing frames.

Positive samples are collected as ground-truth blinks with a linear SVM classifier (called FRP SVM) which is trained from artificially generated sequences. The negative sample was taken from video, which did not blink, either continuously open or continuously close eyes. During the test, the classifier is executed as a scan window. In addition to the beginning and end of video sequence, the 8-dimensional features of each closed eye frame are calculated and classified by FRP SVM[16].

3. Analysis and Discussion of Experimental Results

3.1. Experimental Preparation
In order to compare the performance of our algorithm on different data sets, We used the ZJU blink video database and Self-built blink video database to experiment.

Self-built blink video database: The data set consisted of 30 subjects, roughly equal numbers of men and women, ranging in age from 20 to 50, in well-lit indoor locations. No other instructions were given to the subjects during the collection process. Each person collected several hours of data, including changes in lighting (day and night), posture and facial decorations (glasses). Video segments in the database were divided into training and testing parts. The former was used to train FRP SVM classifier, and the latter was used to test the effect of FRP SVM classifier. In the ZJU blink video database, the first 40 videos were selected as training classifier, and the last 40 videos were used to test the effect. In the self-built database, we selected 100 video segments for training, and the remaining 100 video segments for testing. Each video segment had different length and contained different blink times.

In this paper, video with blinking process is taken as a positive sample, and video with eyes open or closed for a long time is taken as a negative sample.

3.2. Model Selection
The two models are used for training.

One-step method was the first method used. It connects L0 and L3 directly(see Figure 4). This method takes the pixel value of the pixel on the line and calculates the FRP value.

![Figure 4. A picture of the eye area using one-step method](image)

The second one is to adopt the three-step method which was described in section 2.2(see Figure 5).

![Figure 5. A picture of the eye area using three-step method](image)
4. Conclusion
This paper presents a real-time blink detection algorithm, which uses the change of the pixel value of the eye image to determine whether to blink or not. The algorithm was tested on two data sets and VSM...
classifier was used twice for simple blink detection. The algorithm was verified in real environment, and the experimental results show that the algorithm performs well in robustness, accuracy and detection speed. The algorithm proposed in this paper has strong operability and lower cost than traditional blink recognition.

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