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A Template Matching and Support Vector Machine Based Approach for Human Eye Localization and Verification

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***Abstract**: Eye localization is required in many applications like eye gaze tracking, iris recognition, auto-stereoscopic displays, face detection and face recognition, human–computer interfaces, iris driver drowsiness detection, security, and biology systems. In this paper, template based eye detection is described. The template is correlated with skin region of the face image. The region which gives maximum correlation with template refers to eye region. Verification of detected eye is also done by two methods 1) by measurement of Euclidean distance between detected eye and eye template and 2) by using support vector machine. The method is simple and easy to implement. The effectiveness of the method is demonstrated in both the cases like open eye as well as closed eye through various simulation results.*

Keywords: *Eye detection, template matching, Cross-correlation, Euclidean distance.*

1. INTRODUCTION

Human face image analysis, detection and recognition have become some of the most important research topics in the field of computer vision and pattern classification. Recognition of human faces is an actively developing research field. Various researches on human-computer interaction or other types of application based on eye gaze have been done. Apart from it, eye detection is a crucial aspect in many useful applications ranging from face recognition and face detection to human computer interface design, and driver behaviour analysis. By locating the position of the eyes, the gaze can be determined.

In literature, there are many techniques available for automatic eye detection.
In [1], iris geometrical information is used for determining a region candidate that contains an eye in the whole image, and then the symmetry is used for selecting the pair of eyes. [2] uses physiological properties and appearance of eyes as well as head/eye motion dynamics. Probabilistic based appearance model is used to represent eye appearance. In [3], iris geometrical information is used for determining a region candidate that contains an eye in the whole image, and then the symmetry is used for selecting the pair of eyes.[4] uses the structure of the eye region as a robust cue to find eye pair candidates in the entire image. Then eye pairs are located by a support vector machine-based eye verifier. This method fails when eyes are closed. In [5] advantages of two existing techniques, feature based method and template based method, are combined.[6] uses edge vector to detect eye.[7] uses map of eyes flexible thresholding and geometrical tests. In [8] eye candidates are extracted within face regions then, using the anthropological characteristics of human eyes, the pairs of eye regions are selected. [9] uses the geometry and shape based rules on connected regions to detect eye. [10] uses rules derived from the spatial and geometrical relationships of facial components.[11] uses morphological operations which fails when one or both eyes are closed.

Although much effort has been spent and some progress has been made, the problem of automatic eye detection is still far from being fully solved owing to its complexity. Factors including facial expression, face rotation in plane and depth, occlusion and lighting conditions, all undoubtedly affect the performance of eye detection algorithms. The method proposed in this paper also involves verification of detected eyes.

The rest of the paper is organized as follows. The template based method is described in section 2. The verification of detected eye using Euclidean distance and SVM tool is described in section 3. The implementation results and verification results are shown in section 4. The conclusion is shown at the end.

2. A TEMPLATE MATCHING APPROACH FOR EYE LOCALIZATION

The template matching approach presented here is an enhancement of the approach presented in [12]. Our presented eye detection technique involves three steps namely skin segmentation, eye localization and eye verification. Verification step is added to the previously presented method [12]. In our presented approach, the detected eye is verified using Euclidean distance and a machine learning tool Support Vector Machine (SVM).

2.1 Skin Segmentation

2.1.1 Color Space Selection

Here our input image is 2D front face color image. From front face image skin portion is separated out using the method suggested in [13,14]. The goal is to remove the maximum number of non-face pixels from the images in order to narrow the focus to the remaining predominantly skin-colored regions. For this purpose we need to select appropriate color space from the wide variety of choices such as RGB, HSV, CMYK, YCbCr etc. From these, RGB (red-green-blue), HSV (hue-saturation-value) and YCbCr are widely used [15]. In the RGB model, each of the three components may exhibit substantial variation under different lighting environments. The results of YCbCr and HSV are more robust to lighting variations because in both the color spaces, color classification is done using only pixel chrominance. It is expected that skin segmentation may become more robust to lighting variations if pixel luminance is discarded and it is also verified by results. Here HSV color space is preferred for color classification because of its similarities to the way human tends to perceive color. It decouples the chrominance information from the luminance information. Thus we can only focus on the hue and the saturation component.

2.1.2 Setting Threshold and Binary Image Creation

After choosing the suitable color space, the next step is to separate the skin colored region from the given input image. For this, the best technique is to apply threshold.

When these threshold values are applied to the input image, the new binary image is formed in which the portions satisfying the conditions is made white and the remaining portion is made black. Figure 1 shows result of skin segmentation. This is a binary image created from a RGB input image. The thresholding is done on the basis of the HSV values.

(a) (b)

Figure 1: Skin segmentation (a) input image (b) image after skin segmentation

2.2 Eye Localization

The three steps involved in eye localization process are discussed in following subsections.

2.2.1 Template Creation

For any template based approach, it is very much necessary to obtain a template which is a good representative of the data. In this technique, eye template is created by averaging the intensities of a set of eye images.

In training images a good subset of the eyes those are clear, straight, and representative of typical lighting/environmental conditions is found. It is also important that these images be properly aligned and scaled with respect to one another. To this end, considerable time was spent for manually segmenting, selecting, and aligning eye images. At the end 18 eye images were chosen. These cropped images were first converted into gray scale and then the average was found which gives final template. The eye template *T* is formally defined as,

$$T(i,j) = \frac{1}{N}\sum_{k=1}^{N} Ek(i,j) \qquad (1)$$

Where *N* is the number of eye images used for eye template creation and *Ek* is the eye image. *Ek*(*i*, *j*) and *T*(*i*, *j*) represent the pixel values of the pixel of *Ek* and *T* respectively. Thus, our final template for eye detection is a result of averaging together the 18 eye images. The actual template used in the matched

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filtering is of size 40×22 pixels. The template generated and used in the experimentation is shown in figure 2.

2.2.2 *Resizing Template*

It is observed that the size of the eye is proportional to the size of the front face image. This observation is

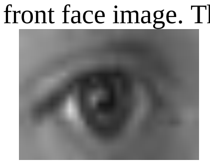

Figure 2: Created template image

used for resizing the eye template in the proposed technique. To handle the detection of eyes of various sizes, eye template need to be resized to make it appropriate for the detection of eye in the image.

$$wi^e = \frac{wr^e}{wr^f} wi^f \qquad (2)$$

By keeping the aspect ratio of the eye template same, it is resized to the width obtained in above Equation 2. Where wi^f and wr^f be the widths of the input face image and the reference face image respectively and wi^e and wr^e are the widths of input eye image and the reference eye image respectively.

2.2.3 *Localization*

To search an eye in the image *I*, eye template *T* is moved over the skin area of the image and normalized cross correlation coefficient (NCC) [16] is computed at every pixel. NCC at point (*x*, *y*) is defined in Equation (3) as,

$$NCC(x,y) = \frac{\sum_{u,v}[I(u,v)-\bar{I}_{x,y}][T(u-x,v-y)-\bar{T}]}{\sqrt{\sum_{u,v}[I(u,v)-\bar{I}_{x,y}]\sum_{u,v}[T(u-x,v-y)-\bar{T}]}} \qquad (3)$$

where sum is performed over *u*,*v* under the window containing T positioned at (*x*,*y*). $\bar{I}_{x,y}$ and $\bar{T}$ are the average of brightness values of the portion of the target image under the template and template image respectively. Values of NCC lie between -1.0 and 1.0. Where it is found maximum, a rectangle of template size is drawn around it to show detected eye. Value of NCC closer to 1 indicates a better match.

3. EYE VERIFICATION

To determine whether a detected eye is a true eye or not two methods are used namely verification using Euclidean distance [17] and verification using SVM tool [18,19].

3.1 Eye Verification Using Euclidean Distance

Here to determine whether a detected eye is a true eye or not, shape based eye verification is performed. To measure the similarity, Euclidean distance between the two sets (one for template and another for detected eye) of mean is used, which is estimated as follows:

$$\text{Distance} = \sqrt{(|M^T| - |M^E|)^2} \qquad (4)$$

Where M^T and M^E are mean of eye template and detected eye respectively. Similarity distance between them is calculated using Equation (4). If the value of *distance* is less than a pre estimated threshold, detection is accepted otherwise it is rejected.

3.2 Eye Verification Using SVM Tool

A Support Vector Machine (SVM) [18, 19] is a machine learning tool that is becoming popular due to its success in pattern recognition applications; though, is not limited to this one application. SVM tries to minimize the upper bound on the expected risk. It is always guaranteed to find the global minima. Therefore the generalization ability (error in predicting data not present in training set) is more accurate compared to other classifiers. Without proper quality and quantity of data, the generalization achieved by SVM would be better compared to other classifiers. Moreover, the time required for developing a SVM model is much lower because of the need for fewer data in training. Here prediction of unseen data is done by considering only the Support Vectors and hence presence of outliers in the training set may not influence the generalization accuracy of SVM.

In this work libsvm-2.91 tool [19] is used for eye verification. The choice of the appropriate Kernel for a specific application is again problem dependent and often a difficult task. The different kernel like Linear, Polynomial, Radial Basis Function, Sigmoid and accordingly parameters i.e. degree, gamma, cost co-efficient are adjusted to improve the verification accuracy.

4. EXPERIMENTAL RESULTS

4.1 Data Acquisition: In this work CVL (CVL is library for image and data processing using graphics processing units (GPUs)) dataset [20] is used, which contains total 114 persons with 7 images of each. Resolution of each image is 640 x 480. All the Images are in JPEG format captured by Sony Digital Mavica under uniform illumination, and with projection screen in background. The other Indian face database is used which contains images of 40 distinct subjects with eleven different poses for each individual. Resolution of each image is 640 x 480. One dataset is also produced by us, having images of 50 front faces with dynamic lighting condition with screen resolution of 2848 × 2144 which also includes closed eyes.

4.2 Results of Eye Detection

To create eye template, a set of eye images of 18 people is considered. NCC is used to localize the eye. Points having maximum NCC values are declared as the detected eye. This experiment is performed on 100 images of CVL dataset, 40 images of Indian face database and 50 images of general dataset. For left and right eye detection two different left and right eye templates are used respectively. Figure 3 shows examples of some of the positive detections and Figure 4 shows examples of some of the false detections. Generally cause of false detection is spectacles. Accuracy of the localization is defined by (*genuine localization/total sample*) × 100. The accuracy of the presented method on the above mentioned database is obtained to be 91%. The average time to detect an eye from a front face image is approx. 1.42 seconds with Matlab environment.

Figure 3: Positive detection

Figure 4: False detection

4.3 Results of Eye Verification

Here for eye verification Euclidean distance threshold is used which gives 91% accuracy. Libsvm-2.91 tool is also used for verification. Here template is of size 40×22 and so the detected eye is also of the same size. Therefore, 880 pixel intensity values are in one feature vector. The different parameters are set for accuracy measurement. The maximum accuracy is found to be 91.67%. The maximum accuracy was obtained with RBF kernel using parameter values of Cost and gamma to be 1 and 0.001 respectively. However, in this experimentation few other combinations were also found which gave the same accuracy.

5. CONCLUSION

The proposed method does not have any effects on the detection of eyes from different environments. The constraint for getting very good result is that the template has to be recreated for different datasets otherwise it degrades the performance of detection. Here template is moved over the skin region, so ideal skin segmentation is required. Method does not give accurate result for images with spectacles. The required detection time is approx. 1.42 seconds with Matlab environment. Experimental results on real front face images also demonstrate the effectiveness of the presented approach.

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