A Simple and Effective Real-time Eyes Detection Human Detection Without Training Procedure

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Abstract: - An effective and real-time eyes detection system based on the symmetric and geometric relationships of human-eyes region in gray-level images is presented. In order to reduce the search effort and eliminate the noise impact, we first perform the edge processing with Sobel filter. We then make use of the characteristics of symmetric relationship of human-eyes region to find out the possible regions of human eyes. Moreover, we use the geometric characteristic of human-eyes region to preliminarily exclude the region without eyes and reach the locations of possible eyes regions as quickly as we can,. Finally, to merge all possible regions with eyes into one and to exclude the regions without human eyes effectively, the eyes verification process is also proceeded. The superior performance of the eyes detection of the proposed method is justified in experiments on a large number of images. The demonstration of our work is available at: http://www.ee.tku.edu.tw/~dsp/tkufd

Key-Words: - Eyes Detection, Face Detection, Real-time, Sobel Filter.

1 Introduction

Till now face detection and recognition is still a very popular research topic. For 20 years, a great deal of organizations and researchers gets involved in this field, and they make plentiful achievements. Some have already made practical systems and tools related to system development kit (SDK). researches of face detection involve image processing, sketch recognition, neural network … etc.

Despite static images or dynamic films, how to examine the exact facial position in accordance with the current researches [1] may be categorized as follows: (1) Appearance-based method: to train the sample of faces, (2) Feature-invariant method: to position faces by geometric relationship, (3) Template matching method: to establish the standard facial samples and (4) Knowledge-based method: to detect the important characteristics in faces (such as eyes, nose, mouth) by geometric position, and then to integrate these characteristics in order to decide facial position[2-3]. Yang and Huang [2] have claimed three levels of network structures of facial characteristics to detect faces. But the method is complicated. Turk and Pentland[4] applied eigen-face to recognize faces. The method received a good evaluation, but it must decrease the dimensions of the matrix to avoid the tedious calculation. Sung [5] and Rowley[6] have accomplished the most effective detection, but it required many training samples, particularly for non-face images. Recently, Heisele et al. [7] in MIT have also developed many face detection systems. However, various techniques mentioned above still require the excessive amount of operations. Several papers [8-14] for immediately detecting faces on images have also been published, but the detection rate isn’t good enough. Han et al. [11] stated that the detection of a 512 × 339 gray-level image took about 18 seconds, but a good detection rate (about 94%) was obtained with self-defined image database. Face matching can decrease the feature dimension of image by using the facial block samples with trained neural network [15][16][17]. Paul Viola and Michael Jones[18] They are use Adaboost and cascade make real time face detetion.Yang and Paindavoine [19] described a real time vision-embedded system based, respectively, on field programmable gate array (FPGA), zero instruction set computer (ZISC) chips, and digital signal processor (DSP)) to locate faces in video sequences. The success rates of face tracking and identity verification are, respectively, 85% (ZISC), 92% (FPGA), and 98.2% (DSP) by using the Olivetti Research Laboratory (ORL) database which contains 400 grayscale images of 40 persons. For the three embedded systems, processing speeds for image size of 288x352 are, respectively, 25 images/s, 14 images/s, and 4.8 images/s. The result shows that the recognition rate increases as the processing speed decreases.

From the standpoint of practicality, this paper proposes a fast and effective facial detection system via eyes detection, which belongs to the feature-invariant category. We design a hierarchical window based on the facial features as a operating mask for human-eyes detection so as to be adaptable for different face sizes in images. By considering the symmetric relationship of human-eyes regions, we first determine the center points of both eyes to find out the possible regions of human eyes. Then, to preliminarily exclude the region without eyes and quickly reach the fixed locations of possible face region, we look for the horizontal line of both eyes by means of the geometric characteristic of human-eyes regions.

Due to the different lengths of the scanning window, the horizontal lengths of all possible human-eyes regions may be different. We design a mechanism to merge these possible regions with eyes into one. Finally we use the features of eyes to make face confirmation and remove effectively the region without human face. Because we consider the relationship of geometric position to detect human face, the test patterns in our experiment should contain two eyes in images. This article can be summarized as follows: the second part introduces face detection techniques including pre-processing of images, hierarchical window searching, the features of symmetric relation, the features of geometric relation and verification. The third part describes the results and discussions of the experiments for static image and video image. The fourth part is the conclusion.

2 Techniques for eyes detection

In the pre-processing of image, we adopt an exhaustive search approach to detect possible face in an image. In this method, image windows of various predefined sizes are moved across the image. When a window is moved to a new position, a decision is made whether a face is contained inside the window. It is easy to realize that such a scheme will be computationally very heavy because it has to search all locations of the image for all possible window sizes. In order to reduce the search effort, we first perform the edge processing with Sobel filter operation. The proposed system mainly deals with the gray-level images, and for the color images they are transformed to the gray-level images. The whole steps of eyes detection system are outlined as follows:

(1)Do the edge processing with Sobel filter for horizontal and vertical edges of image.
(2) Use pre-established operation masks to search the central line of the eyes.
(3) Search the horizontal line of eyes.
(4) Segment the eyes blocks.
(5) Confirm the eyes.
(6) Mark out facial location.

2.1 Searching the set of Windows

To accomodate the different sizes of faces in image, we define the horizontal width (H) and the vertical height (V) of each hierarchical window for human eye in eq.(1) and eq.(2), respectively,

$$H(k)=H(0)(1+k*fh) \quad (1)$$

$$V(k)=V(0)(1+k*fv), \quad 0 \leqq k \leqq 11 \quad (2)$$

where fh is the parameter of horizontal ratio and fv is the parameter of vertical ratio. Here, the parameters, fh and fv, are set to be 0.15 and 0.06, respectively. Table 1 tabulates the values of the horizontal width (H) and the vertical height (V) of each scanning window for human eyes. Because the number of pixels is an integer, the values of H and V are computed with rounding error.

Table 1: The scanning window for human eyes, where H and V are the values of horizontal width and vertical height, respectively. (unit : pixels)

K	0	1	2	3	4	5	6	7	8	9	10	11
H	48	55	62	70	77	84	91	98	106	113	120	127
V	16	17	18	19	20	21	22	23	24	25	26	27

For a gray-level image (256 x384x256), the limits of minimum value of the scanning window for human eyes are shown in Fig.1 (a) and (b), and the limits of the maximum value of the scanning window for human eyes are shown in Fig.1 (c) and (d). According to the scanning window shown in Table 1, we search the whole area in the edged image. If the scanned image block satisfies our rules, we record the related information of the position of possible region having eyes.

From the practical point of view, it is reasonable to define the upper limit and lower limit values of the horizontal width of the scanning window. In fact, the frame size of image captured by live - video is 320x240. Here we set the upper limit value to be 127 pixels and the lower limit value to be 48 pixels in our experiment. Because the CCD is hung up in the secret position, it is impossible for the human face close to the CCD. Usually, the distance must be at least 30cm. These limit values should change if the resolution of CCD changes.

(a) (b) (c) (d)

Fig.1 (a), (b) The range of lower limit of the scanning window for human eyes shown on image, (c), (d) the range of upper limit of the scanning window for human eyes shown on image

2.2 The features of symmetric relationship

The human face block has three characteristics of symmetric relationship: the number of horizontal edge pixels of both eyes, the position of irises of both eyes, and the blank areas below both eyes. According to these characteristics we define the following conditions to detect the possible region of human eyes in the first step. Before illustrating these conditions we define two parameters, horizontal edge number (N_h) and vertical edge number (N_v), in one block area with eq. (3) and eq. (4),

$$N_h = \sum_{i=1}^{m} \sum_{j=1}^{n} E_h(i, j) \text{---------------------(3)}$$

$$N_v = \sum_{i=1}^{m} \sum_{j=1}^{n} E_v(i, j) \text{ ---------------------(4)}$$

where and are the length and width of one block, respectively, and are the horizontal edge and vertical edge of binarized image with Sobel operation, respectively. Fig.2 shows an example of the horizontal edge and vertical edge of binarized image with Sobel operation.

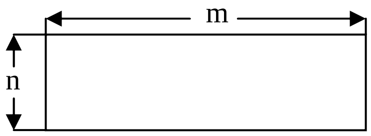


Fig 2: Scanning window in horizontal and vertical edge areas.

Term 1: Three roughly - partitioned windows

(1) Set the rough ratio of human eyes to be 1/3, as shown in fig.3. We use eq. (5) to record the related positions (L1, L2, R1, and R2) of image in fig.6 for each human face block,

$$D_{L1-L2} = D_{R1-R2} = D_{L2-R1} = \text{H/3…-….(5)}$$

where is the distance from point x to point y, and H is the value of horizontal width of each hierarchical window for human eye.

(2) Determine whether the horizontal edges of right and left eye regions are symmetric.Set the critical value of comparison to be which is defined by eq.(6),

$$\mathrm{T}_1 = \left| N_{hr} - N_{hl} \right| \text{ ………………………..(6)}$$

where and are the numbers of horizontal edges of right and left eye region, respectively, and obtained by eq. (3). When T_1 > 10, it indicates not in the region of human eyes

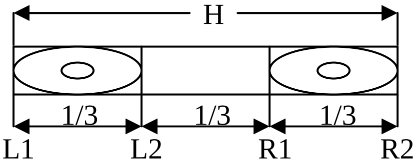


Fig.3 Three roughly–partitioned sections of human-eyes block

Term 2: Six finely – partitioned windows

(1) Set the fine ratio of human eyes to be 1/6, as shown in Fig.4, to determine the related positions (Lc, Fc, and Rc). Lc is the central point of the left eye, Fc is the mid point of two eyes, and Rc is the central point of the right eye.

(2) Determine whether the irises of two eyes are symmetric. Set the critical value of comparison to be which is defined by eq.(7),

$$\mathrm{T}_2 = \left| N_{hir} - N_{hil} \right| \text{ -------------------------- (7)}$$

where and are the numbers of horizontal edges of iris region of right and left eye, respectively, and obtained by eq. (3). When T_2 > 10, it indicates not in the region of human eyes

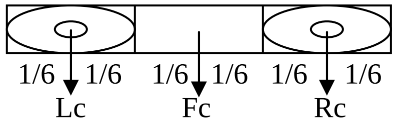


Fig.4 Six finely-partitioned sections of human-eyes block

Term 3:The blank areas below two eyes

(1) Define the blank areas below two eyes as shown in Fig.5, where V is the vertical height of each hierarchical window for human eye.

(2) Compute the horizontal edges in the areas below two eyes. The value of the number of blank areas is the same. Set the critical value of comparison to be which is defined by eq.(8),

$$\mathrm{T}_3 = \left| N_{hbr} - N_{hbl} \right| \text{ -------------------------- (8)}$$

where and are the numbers of horizontal edges of the area below right and left eyes, respectively, and obtained by eq. (3). When T_3 > 10, it indicates not in the region of human eyes.

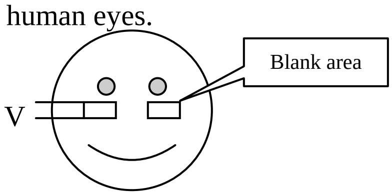


Fig.5 The blank areas below two eyes

2.3 The features of geometric relationship

The human face block has three characteristics of geometric relationship:(a) relationship of horizontal edge between human-eyes region and mid-region between two eyes, (b) symmetric relationship of vertical edges in the top and bottom regions of the eyeball based on the horizontal levels of both eyes, and (c) relationship of vertical edge and horizontal edge in human-eyes blocks. According to these characteristics, we define the following rules to preliminarily exclude area without face and automatically detect true position of the human eye.

◎ Rule 1: Use the horizontal edge to detect the possible region of eyes, i.e., determine whether the total number of horizontal edges in both eyes is greater than twice the number in M-region, as shown in Fig.6. Set the critical value of comparison to be which is defined by eq.(9),

$$T_4 = \left| N_{hl} + N_{hr} - 2N_{hm} \right| \text{------------------ (9)}$$

where , and are the numbers of horizontal edges of left eye, right eye, and M–region, respectively, and obtained by eq. (3). When $T_4 > 100$, it indicates not in the region of human eyes.

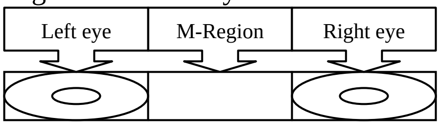


Fig.6 The mid-area between two eyes defined as M-region.

◎Rule 2: First, sweep horizontally the vertical edges of both eyes to obtain the horizontal level of eye-ball, as shown in Fig.7. Then, determine whether the vertical edges in the regions of the eyeball of two eyes are symmetric. Set the critical value of comparison to be which is defined by eq.(10),

$$T_5 = \left| N_{vil} - N_{vir} \right| \text{--------------------------- (10)}$$

where and are the numbers of vertical edges of iris of left eye and right eye, respectively, and obtained by eq. (4). When $T_5 < 10$, it indicates not in the region of human eyes.

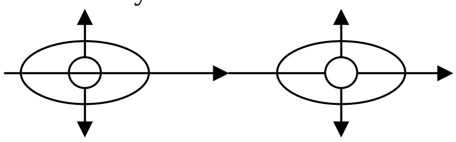


Fig.7 Sweeping horizontally the vertical edges for both eyes

◎Rule 3: Determine whether the total number of horizontal edges is greater than that of the vertical edges in both L and R regions, as shown in Fig.8. Set the critical value of comparison to be which is defined by eq.(11),

$$T_6 = \left| (N_{hl} + N_{vl}) - (N_{hr} + N_{vr}) \right| \text{------- (11)}$$

where and are the numbers of vertical edges of left eye and right eye, respectively, and obtained by eq. (4). When $T_6 > 10$, it indicates not in the region of human eyes.

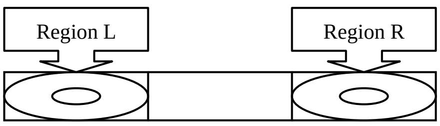


Fig.8 The regions of left and right eyes defined as region L and R, respectively.

2.4 Verification

We have two purposes for eyes verification: one is to merge all possible regions with eyes into one and the other is to exclude the regions without human eyes. Owing to the different lengths of the scanning window, the horizontal lengths of all possible human-eyes regions may be different. We need a mechanism to merge these possible regions having eyes. From all possible human-eyes regions we only choose those regions where the corresponding irises are close enough in some range, and then preserve the region which has the largest scanning window. To exclude those regions without human eyes, we use two methods to aim our goal. One is the back propagation neural network (BPNN)[6] and the other is the proposed verification system without training.

We use FERET database as the training samples of human face and locate manually eye regions. The flow chart of the proposed human-eyes verification without training is shown in Fig.9. In this verification process we check the features mentioned in sec. 2.2 and 2.3 again with more exact threshold value for human-eyes verification. Finally, we label the face region according to the proportion of face and the adjustable scanning window.

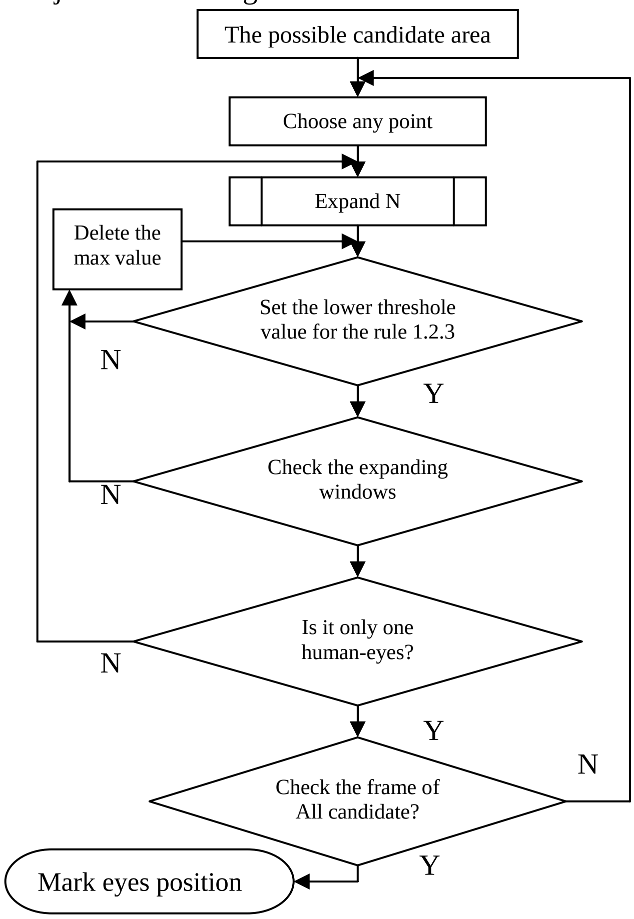


Fig.9 ： Flow chart of the proposed human-eyes verification without training.

3 Experimental results and discussion

In this paper, the specification of PC computer is Pentium 4, 1.8GHz, 256 MB-DRAM,Window-2000. The experimental subjects of the human eyes

detection include static images and video images. There are many databases of gray-level image, such as FERET, MIT, BioID, AR…etc, but the resolution and the quality of images have not been unified, particularly for the color image database. For static images, FERET database is used for experiment. The FERET database amounts to 2164 pieces of gray-level image and can be downloaded from the Website.
(http://www.itl.nist.gov/iad/humanid/feret/feret_master.html).

3.1 Static image experiment

The correct rate is 95%(2056/2164) and 95.7%(2071/2164) for FERET database under BPNN verification system and the proposed verification system without training , respectively. It takes about 0.02 second for detecting each image under both verification systems. Both verification systems obtain superior result. The detection rate of the proposed verification system without training is better than the BPNN verification system and no more time consumption is needed for the proposed verification system. It takes only 0.05 second for detecting each color image and the correct rate is 90%(296/328) for WCset database, where the color images are transformed to the gray-level images. In general, we get 30 frames of image per second captured by CCD or DV, i.e. it takes about 0.03 second for a frame. For a real-time system, we can satisfy the requirement of time in eyes detection for static image, but not in video image. For the purpose of real-time face recognition, we still have to consider the matching problem.

3.2 Performance comparison using different features

We compare the performance using different features of symmetric and geometric relationships. We have three features, namely, term 1, 2, and 3, of symmetric relationship, and another three features, namely, rule1, 2, and 3, of geometric relationship. We divide the FERET database (2164 pieces) into six blocks: 1-100 as block 100, 101-500 as block 500, 501-1000 as block 1000, 1001-1500 as block 1500, 1501-2000 as block 2000, and 2001-2164 as block 2164. Fig. 10 shows the curved lines of the detection rate of possible eyes regions vs. features for each data block. Due to different backgrounds and angles of human face in each image, the detection rate in fig.10 is different for each data block. Fig.10 demonstrates that the requirements by the features of symmetric relationship are more loose than by the features of geometric relationship, and the detection rate of possible regions with eyes decreases with increasing the number of features in either relationship. The result matches the normal consideration of detection process.

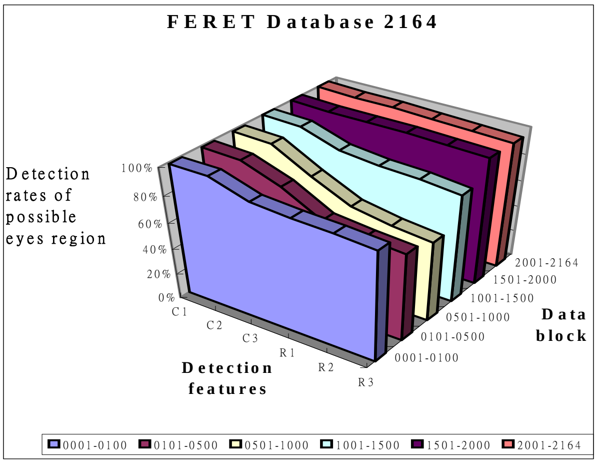
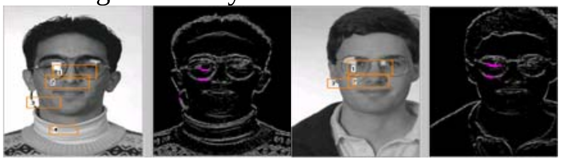


Fig. 10 The curved lines of the detection rate of possible eyes regions vs. features for each data block. (The representation marks for different detection features are shown below:
C1 : term1 only; C2 : C1 + term2; C3 : C2 + term3; R1 : C3 + rule1; R2 : R1 + rule2; R3 : R2 + rule3 .)

Table 2 Analysis of wrong detection for each block of FERET database (PR1 : possible regions without human eyes only, PR2 : possible regions with and without human eyes)

Blocks of FERET database	Number of image of wrong eyes detection before verification			Number of image of wrong eyes detection after verification
	PR1	PR2	Total sum	Total sum
0001-1000	2	13	15	2
0101-0500	19	110	129	20
0501-1000	45	143	188	47
1001-1500	20	66	86	21
1501-2000	2	12	14	2
2001-2164	1	5	6	1
Total	89	349	438	93

After verification process, the number of image of wrong eyes detection in PR2 part is greatly reduced, and certainly wrong detection of those images in PR1 can't be revised as tabulated in table 2. This depicts that the procedure of integration of possible regions with eyes and exclusion of possible regions without eyes is effective after verification process for each data block. This is because the concept of the proposed eyes detection method is like a shape of inverse triangle and isn't a shape of pyramid. If we check the features with exact threshold value used in verification for the detection of possible regions with eyes, we can't easily detect the position of iris and thus find the possible regions with eyes. We have some wrong face detection examples of image as given in. Fig. 11 (a) and (c) show the gray-level images of face with glasses. Because the reflected lights are on the glasses of face, the possible region with eyes becomes an asymmetric region. Thus the possible region with eyes is excluded.



(a) (b) (c) (d)

Fig. 11 (a) and (c) the gray-level images of face with glasses, (b) and (d) the edged images via Sobel filter processing.

4 Conclusion

We propose a hierarchical window based on the facial features as a operating mask for human eyes detection so as to be adaptable for different face sizes in images. We first make use of the characteristics of symmetric relationships of human-eyes region to find out the possible regions of human eyes. Then, we use the geometric characteristic of human-eyes region to preliminarily exclude the region without human eyes and quickly reach the locations of possible face regions.Finally,after eyes verification we obtain real-time face detection. The superior performance of the face detection of the proposed method is justified in experiments on a large number of images under 256*384*256 resolution. We also hope to accomplish a face recognition system using the proposed eyes detection method in the near future.

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