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Iris Recognition Using Modified Hierarchical Phase-Based Matching (HPM) Technique

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Abstract

This paper explores an efficient algorithm for iris recognition based on Hierarchical Phase-Based Image Matching (HPM) technique. One of the difficult problems in feature-based iris recognition is that the matching performance is significantly influenced by many parameters in feature extraction process, which may vary depending on environmental factors of image acquisition. The proposed system is designed for applications where the training database contains an iris for each individual. The final decision is made by HPM at "matching score level architecture" in which feature vectors are created independently for query images and are then compared to the enrollment templates which are stored during database preparation for each biometric trait. Based on the proximity of feature vector and template, each subsystem computes its own matching score. These individual scores are finally combined into a total score, which is passed to the decision module. In this proposed technique, the use of phase components in 2D (two dimensional) discrete Fourier transforms of iris images makes possible to achieve highly robust iris recognition in a unified fashion with a simple matching algorithm. The technique has been successfully applied and also clearly demonstrates an efficient matching performance of the proposed algorithm.

Keywords: *Phase-based image matching, phase-only correlation, phase-only matched filtering, biometrics, iris recognition.*

1. Introduction

1.1. Overview of the work

A major approach for IRIS recognition today is to generate feature vectors corresponding to individual iris images and to perform iris matching based on different metrics. One of the difficult problems in feature based iris recognition s that the matching performance is significantly influenced by many parameters in feature extraction process, which may vary depending on environmental factors of image acquisition. This paper presents an efficient algorithm for iris recognition using hierarchical phased-based matching (HPM). It eliminates steps like normalization and eyelid masking and also improves the speed of matching by hierarchical based matching method. The use of phase components in 2D Discrete Fourier Transforms of iris images makes possible to achieve highly robust iris recognition in a unified fashion with a simple matching algorithm.

1.2 Existing work

The aim of biometrics is to identify individuals using physiological or behavioral characteristics such as fingerprints, face, iris, retina, and palm prints. Among many biometric techniques, iris recognition is one of the most promising approaches due to its high reliability for personal identification [1]. The biometric person authentication technique based on the pattern of the human iris is well suited to be applied to any access control system requiring a high level of security. Compared to fingerprint, iris is protected from the external environment behind the cornea and the eyelid. No subject to deleterious effects of aging, the small-scale radial features of the iris remain stable and fixed from about one year of age throughout life. For Iris recognition, R.Wildes solution includes (i) a Hough transform for iris localization, (ii) Laplacian pyramid (multi-scale decomposition) to represent distinctive spatial characteristics of the human iris, and (iii) modified normalized correlation for matching process [2]. In matching two irises, Daugman's approach involves computation of the normalized Hamming distance between iris codes, whereas Wildes applies a Laplacian of Gaussian filter at multiple scales to produce a template and computes the normalized correlation as a similarity measure [3]. J.Daugman's and R.Sanchez-Reillo's systems are implemented exploiting (i) integro-differential operators to detect iris inner and outer boundaries, (ii) Gabor filters to extract unique binary vectors constituting iriscodeTM, and (iii) a statistical matcher (logical exclusive OR operator) that analyses basically the average Hamming distance between two codes (bit to bit test agreement). Because of unified reference database of iris images does not exist, a classic performance comparison of the described systems is not trivial. One of the major challenges we encountered for iris recognition system design, our research focus on the second block both in charge of (i) the enrolment process,

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and (ii) the matching which quantifies the similitude between two biometric templates [4].

The goal of matching is to evaluate the similarity of two iris representations. Among these are the speed of matching through the normalized Hamming distance, easy handling of rotation of the iris, and an interpretation of the matching as the result of a statistical test of independence [5]. There are advantages and disadvantages to both Daugman's and Wildes' designs. For matching, the Wildes approach made use of more of the available data, by not binarizing the band pass filtered result, and hence might be capable of finer distinctions; how- ever, it yields a less compact representation [6]. Daugman's 2003 paper [7] presents similar results as [8], but with a larger dataset of 9.1 million iris code matches. This number of matches could derive from matching each of a set of just over 3,000 iris images against all others. The match data are shown to be fit reasonably well by a binomial distribution with p = 0.5 and 249 degrees of freedom. This supports the idea that one major research theme in iris bio- metrics is or should be the performance under less-than-ideal imaging conditions. Addressing the above problem, as one of the algorithms which compares iris images directly without encoding , this paper presents an efficient algorithm using phase-based image matching – an image matching technique using only the phase components in 2D DFTs (Two-Dimensional Discrete Fourier Transforms) of given images. The technique has been successfully applied to high accuracy image registration tasks for computer vision applications [9].

In the basic POC concept the Phase component is calculated for the entire image whose entire pixel value is (256x128) as explained in the equation (1) and (2).While calculating the phase component, suppose if the image contains any specular reflection as shown in the Fig. 1 then error will occur.

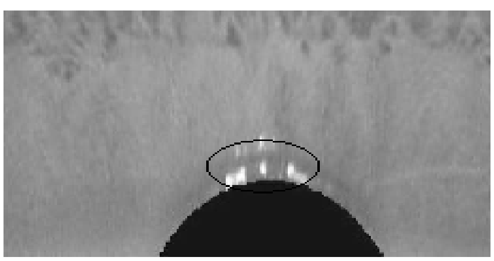

Fig. 1 Image with specular reflection

So in the proposed method we have introduced a hierarchical matching in which, the phase component values are calculated for the subregions of the iris alone as shown in the Fig. 2. So that the image will not be affected by any reflection and also the phase component calculating value will be reduced.

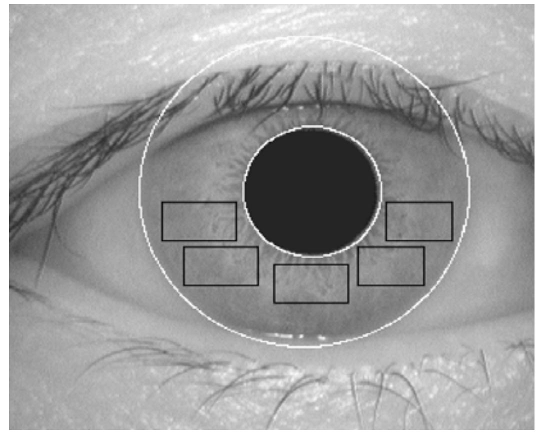

Fig. 2 Extracted subregion of an iris

This paper is organized as follows. Section-2 summarizes the sub pixel image matching using Phase Only Correlation (POC) function. Section-3 proposes a new hierarchical phase based matching algorithm. Section-4 shows the experimental results of the proposed algorithm. Section-5 concludes the paper.

2. Phase Based Matching

Consider two N_1 x N_2 images f (n_1,n_2) and g (n_1, n_2), where we assume that the index ranges are $n_1 = -M_1,\ldots,M_1$ $(M_1>0)$ and $n_2 == -M_2,\ldots,M_2$ $(M_2>0)$ for mathematical simplicity1 and, hence, $N_1=2M_1+1$ and $N_2=2M_2+1$. Let F (k_1, k_2) and G (k_1, k_2) denote the 2D DFTs of the two images. F (k_1, k_2) and G (k_1, k_2) are given by

$$F(K_1,K_2) = \sum_{n_1=-M_1}^{M_1} \sum_{n_2=-M_2}^{M_2} f(n1,n2)\, W_{N_1}^{k_1 n_1} W_{N_2}^{k_2 n_2}$$

$$= A_F(k_1,k_2)\, e^{j\theta f(k1,\,k2)} \quad (1)$$

$$G(K_1,K_2) = \sum_{n_1=-M_1}^{M_1} \sum_{n_2=-M_2}^{M_2} g(n1,n2)\, W_{N_1}^{k_1 n_1} W_{N_2}^{k_2 n_2}$$

$$= A_G(k_1,k_2)\, e^{j\theta f(k1,\,k2)} \quad (2)$$

Where $k_1 = -M_1,\ldots,M_1$, $k_2 == -M_2,\ldots,M_2$, $A_F(k_1,k_2)$ and $A_G(k_1,k_2)$ are amplitude components , $\theta_F(k_1,k_2)$ and $\theta_G(k_1,k_2)$ are phase components. We proposed the idea of the Band-Limited POC (BLPOC) function for an efficient matching of fingerprints, considering the inherent frequency components of fingerprint images. Through a set of experiments, we have found that the same idea is also very effective for iris recognition. In our matching algorithm, K1=M1 and K2=M2 are the major control parameters since these parameters reflect the quality of iris images. In other words, we need to select adequate

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values of these parameters, depending on the iris database to be used. On the other hand, a problem may occur when most of the normalized iris image is covered by the eyelid. In such a case, the extracted region becomes too small to perform image matching. To solve this problem, we extract multiple effective sub regions from each iris image by changing the height parameter h.

The principle used is Phase-Only Correlation (POC) function which matches the phase components of two iris images. Consider two N1, N2 images f (n1; n2) and g (n1; n2). When two images are similar, their POC function gives a distinct sharp peak. If two images are not similar, the peak value drops significantly. The height of the peak can be used as a good similarity measure for image matching and the location of the peak shows the translational displacement between the two images. Thus the idea of Band Limited-POC is introduced for till more efficient matching. On the other hand the BLPOC function provides a much higher discrimination capability than the original POC function. Even though the accuracy in matching is high, its speed is not sufficient in a real time application.

So this project proposes a method of hierarchical matching, in order to provide a sufficient speed in real time applications.

3. Hierarchical Phase Based Matching(HPM) Algorithm

This section describes the modification of the proposed iris recognition algorithm dedicated to system implementation. The designing phases for an iris recognition based on HPM consist of two stages as shown in Fig. 3. They are pre-processing stage and matching stage.

3.1 Pre-processing stage

In pre-processing stage, a single step has to be taken. It is

1) *Iris Localization:* This step is to detect the inner (iris/pupil) boundary and the outer (iris/sclera) boundary in the original image. We model the inner boundary as an ellipse, and the outer boundary as a circle.

3.2 Matching stage

The matching stage consists of three steps. They are

1) *Effective region extraction:* The purpose of this step is to extract the effective regions using the algorithm mentioned in fig 4. So that it can cover the middle portion and the lower portion of the iris.

3) *Matching score calculation:* In this step, we calculate the BLPOC function between the aligned images f (n1; n2) and g (n1; n2) and we evaluate the matching score. In the case of genuine matching, if the displacement between the two images is aligned, the correlation will be peak.

3.3 The Proposed HPM Algorithm

The hierarchical matching is used in the matching score calculation step along with POC.

In a hierarchical matching, consider an aligned iris image f (n1, n2). The POC function is calculated for the latent image f (n1, n2) and let the phase component get be θ_1 and the matching score is evaluated with minimum two database images g (n1, n2) and h (n1, n2) hierarchically. If the phase component θ_1 matches any database image either g (n1, n2) or h (n1, n2), then it will return the matching score value.

Matching can be seen as traversing the tree structure of templates. The matching process starts at the root, the interest locations lie initially on a uniform grid over relevant regions in the image. The tree can be traversed in breadth first or depth first fashion

In the proposed method, the top-to-bottom approach is used. The top-down sequence follows the nodes from the root to the leaf. Its principle functionality is indicated in the following code fragment:

```
01. Input_root_image(i)
02. for each L in leaf(i)
03.    if f(L) =i
04.      marknode_select(L)
05.      return marknode_select(L) for matching score
         calculation
06.        if  genuine matching
07.        return matching score
08.        back to leaf
09.    else
10. top_down_evaluate(s)
```

The function *Input_root_image* gets the actual node as a parameter, which initially is the root of the search graph (line 1). Each leaf *L* of the current node is addressed in a loop (line 2) and for each *L* the formula *f(L)* is evaluated.If *f(L)* is true, the current leaf is marked as relevant (line 4). If *f(L)* fails, the recursion is continued until there is a node which fulfills the formula or until no subsequent node is left (line 6).When applying this code fragment on the iris recognition, the *Input_root_image* get the latent iris image which is the root of the search graph. The loop *foreach* is used to go through the leaves, and then if a leaf node matches with the root node, it will be marked as relevant image and return the image for matching score calculation. Else if it fails to match in the matching score calculation it will return and the recursion will be continued until it matches.

So in the place of matching with a single database image, two database images can be matched

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hierarchically with the input image. So by expanding the hierarchical images the speed will increase.

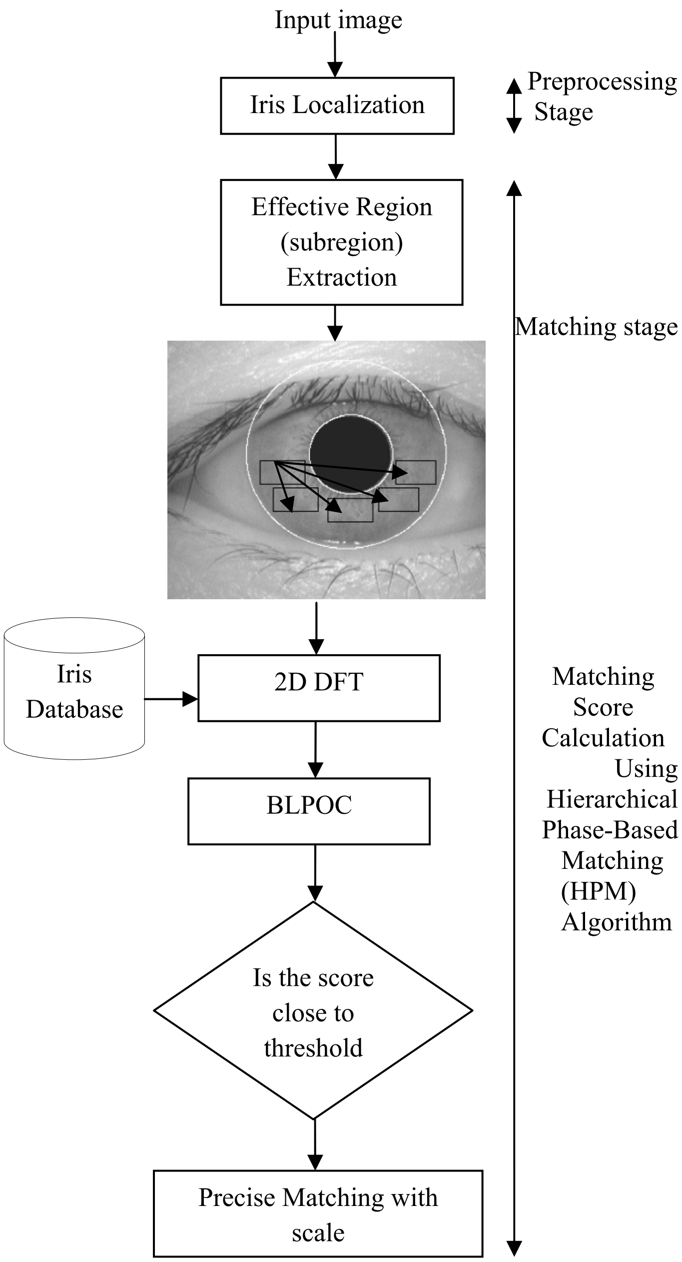

Fig. 3 Flow Diagram of the Proposed Algorithm

3.4 Implementation:

The flow chart for the proposed hierarchical matching is as shown in the Fig. 3. In the basic BLPOC concept the Phase component is calculated for the entire image whose entire pixel value is (256x128) as explained in the equation (1) and (2).While calculating the phase component, suppose if the image contains any specular reflection as shown in the fig-2 then error will occur. So in the proposed method we have introduced a hierarchical matching in which, the phase component values are calculated for the subregions of the iris alone as shown in the Fig. 3. So that the image will not be affected by any reflection and also the phase component calculating value will be reduced.

In the proposed method the concept is implemented as follows. Let the input image be f (n1, n2) and the boundaries of the images are detected and while detecting it will return the center coordinate value and the radius value of the iris and the pupil. Then using the center coordinate values and the radius values along with the proposed HPM algorithm, the subregions are calculated, in a manner that the subregion boundaries should not exceed the iris boundary.

The hierarchical matching is implemented in the matching stage. Here instead of calculating the phase component for the entire image, we are calculating the phase component for the five sub regions (S1, S2, S3 and S4, S5) of the iris.

The first level in hierarchical matching is, take the subregion S1 of the input image f (n1, n2) and calculate the POC value for the S1 of f (n1, n2) with the S1 of the database images. So while doing some n images will be matched. Let the database images be N and the shortlisted images be W, where W<N.

In the second level, get the shortlisted image in a variable W and calculate the POC values for the subregion S2 of f (n1, n2) with the S2 of the shortlisted images. While doing a X number of matched images will be produced and now get that images in a variable X, where X<W. In the third level, get the images of X and calculate the POC function of its subregion S3 with the subregion S3 of the input image f (n1, n2). While doing so, from X we can get a Y number of another shortlisted images, where Y<X.

Finally in the fourth level, by apply the POC function for the subregion S4 of f (n1, n2) with the S4 of Y. While doing so, from Y we can get a Z number of another shortlisted image, where Z<Y.

So now the appropriate image can be detected. So finally N<W<X<Y<Z.

The proposed Hierarchical Matching Algorithm (HPM) is shown in Fig.4 as follows

Algorithm:

Step1: Block partition the Input_root_image f (n1, n2)

(i) Block partition f (n1,n2) into four sub regions (S1, S2, S3, S4, S5)

(ii) To get the blocks, use the following formula. Let xc and yc be the center coordinates of the pupil.

(a) S1= ((x1=xc-65), (y1=yc-10), 45, 25);
(b) S2= ((x2=xc+70), (y2=yc-10), 45, 25);
(c) S3= ((x3=xc-55), (y3=yc+20), 45, 25);
(d) S4= ((x4=xc+55), (y4=yc+120), 45, 25);
(e) S5= ((x5=xc+2), (y5=yc+30), 45, 25);

(Let 45 and 25 be the width and height of the blocks. Let x1 and y1 be the x axis and y axis values of the block S1; x2, y2 be the x axis and y axis values of the block S2; x3, y3 be the x and y axis of the block S3; x4, y4 be the x and y axis of the block S4; x5, y5 be the x and y axis of the block S5.)

Step2: Phase component based matching
Stage 2 explains the hierarchical matching steps for the sub-region phase components by calculating the POC value for the input sub-regions and the database image sub-region.
(Calculate the phase component for S1, S2, S3, S4, S5 using equitation (1) and (2)). Let the phase component for the sub regions be $\theta_{S1}(x, y)$, $\theta_{S2}(x, y)$, $\theta_{S3}(x, y)$, $\theta_{S4}(x, y)$, $\theta_{S5}(x, y)$ for S1, S2, S3, S4, S5 respectively

(i) Calculate the POC for the subregion S1 of input image f (n1, n2) with the subregion S1 of the database images N.
(ii) Calculate the matching score for those subregion
  If POC value of S1 for f (n1, n2) = S1 of some n images of N.
  Then
    Get the matched n images in the variable W
    Where W<N;
(iii) Calculate the POC for the subregion S2 of f (n1, n2) with the S2 of the images in W
  If POC value of S2 for f (n1, n2) = S2 of some n images of W.
  Then
    Get the matched n images in the variable X
    Where X<W;
(iv) Calculate the POC for the subregion S3 of f (n1, n2) with the S3 of the images in X
  If POC value of S3 for f (n1, n2) = S3 of some n images of X.
  Then
    Get the matched n images in the variable Y
    Where Y<X;
(v) Calculate the POC for the subregion S4 of f (n1, n2) with the S4 of the images in Y
  If POC value of S4 for f (n1, n2) = S4 of some n images of Y.
  Then
    Get the matched n images in the variable Y
    Where Y<X;
(vi) Calculate the POC for the subregion S5 of f (n1, n2) with the S5 of the images in Y
  If POC value of S5 for f (n1, n2) = S5 of some n images of Z.
  Then
    Get the matched n image in the variable A
    Where A= Input_root_image f (n1, n2);

Fig. 4 Algorithm for Hierarchical Phase-Based Matching (HPM)

By this method of matching, the threshold value of calculating the BLPOC will be reduced. Compared with the threshold value for calculating the BLPOC for a normalized image of pixel value (256x128), the proposed method can produce better performance.

4. Experimental Results

We tested our project on the database contains 105 gray scale eye images (256 x 128) with 15 unique eyes and 7 different images of each unique eye. The algorithm is implemented in MATLAB 7. We have implemented the proposed hierarchical matching algorithm. The results are tested on the Iris image database. Pertaining to the general approach discussed in the previous sections, corresponding to original image, circular edge detection & pupil center localization, Upper and lower eyelid masking, iris encoding and matching score are shown in the following Fig. 5(a),5(b) respectively.

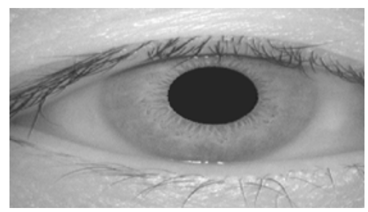

Fig. 5(a) Original Image

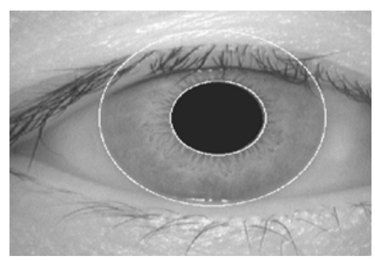

Fig. 5(b) The inner pupil detected image

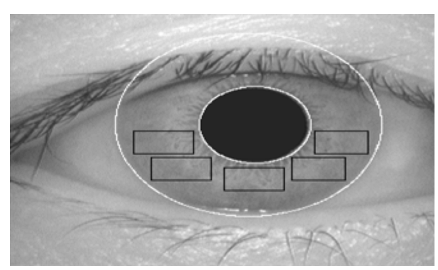

Fig. 5(c) The image with splitted subregions

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After the matching score evaluation, we have achieved minimum genuine matching score 0.122 and the maximum impostor matching score is 0.128. The score between these values can be chosen as a threshold to distinguish between the two classes. Thus for this experiment, we can achieve EER=0%, where the EER (Equal Error Rate) is the error rate where the FNMR (False Non-Match Rate) and the FMR(False Match Rate) are equal. The comparison of the matching score results are shown in the Table. 1

Table.1 Reported EERs

Method	EER(%)
Boles	7.03
Widles	1.04
Doughman	0.08
Proposed Approach	0.00

Thus the result demonstrates a potential possibility of hierarchical Phase based image matching for efficient iris recognition system

5. Conclusion

This paper presented a novel approach for the efficient iris recognition using Hierarchical Phase-Based Matching (HPM) algorithm. Thus the proposed approach can give a highly accurate recognition. Meanwhile, using this proposed method the computational time of phase component has been reduced. The use of phase component in 2D Discrete Fourier Transform of iris images makes possible to achieve highly robust iris recognition in a unified fashion with this proposed matching algorithm.

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