Improved Iris Recognition using Discrete Fourier Transform

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ABSTRACT

This paper presents efficient algorithm for iris recognition using Two dimensional (2D) Discrete Fourier Transform (DFT) and illustrate how increased iris region improves performance. Phase components present in 2D DFTs of given images are used to determine similarity between two images. Algorithm is evaluated with CASIA iris image databases (version 1.0) and it clearly demonstrates that the use of phase components of iris images help to achieve highly accurate iris recognition. By experimentation, it is observed that instead of considering only lower half part of iris, in addition if we consider the portion present in upper half part of iris then it decreases False Match Rate (FMR) significantly as effective region available for iris comparison is increased. Decrease in FMR results in decrease in error rate (EER).

General Terms

Pattern Recognition, Security.

Keywords

Iris recognition, Biometrics, 2D DFT.

1. INTRODUCTION

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 approach due to its high reliability for personal identification [2], [3], [4]. The human iris, which is the annular part between the pupil and the white sclera, has a complex pattern. The iris pattern is unique to each person and to each eye and is essentially stable over a lifetime. Also iris pattern of left and right eye is different. Uniqueness, stability makes iris recognition a particularly promising solution to security.

A major approach for iris recognition today is to generate feature vectors corresponding to individual iris images [2], [3], [4] and to perform iris matching based on some distance metrics. Most of the commercial iris recognition systems implement a famous algorithm using iriscode, which was proposed by Daugman [2]. In this algorithm, 2D Gabor filters are used to extract a feature vector corresponding to a given iris image. Then, the filter outputs are quantized to generate a 2 Kbit iriscode. The dissimilarity between a pair of iriscodes is measured by their Hamming distance based on an exclusive-OR operation. One of the difficult problems in feature-based iris recognition is that the matching performance is significantly influenced by many parameters in the feature extraction process. So to overcome this problem Kazuyuki et al developed iris recognition using phase-based image matching [1]. They developed image matching technique using only the phase components in 2D DFT. Kazuyuki et al considered only lower half part of iris for matching in their work. But this approach faces a problem when most part of normalized iris image is occupied by eyelid. To address this problem new approach for iris recognition has been proposed in this paper. In our system we used a database of normalized iris images. Input image will be a eye image whose iris will be checked against each iris present in iris database. First of all preprocessing is done on input eye image in order to obtain normalized iris image and then it will be matched with each iris present in database. After matching, one matching score is obtained. Then this matching score can be compared with threshold and if matching score is greater than threshold then it is genuine matching else it is a imposter matching.

This paper is organized as follow. Section II focuses on preprocessing which is to be performed on input eye image. Section III introduces the principle of phase based image matching using Phase Only Correlation (POC) function. Section IV describes detailed process of matching algorithm. Section V describes how iris region required for matching can be increased. Section VI is related with experimental results obtained for CASIA version 1.0 database.

2. PREPROCESSING

The proposed algorithm consists of two stages: 1) the preprocessing stage and 2) the matching stage. The purpose of preprocessing stage is to localize the iris region in the captured eye image and to produce a normalized iris texture image with a fixed size (256×128 pixels). A typical eye image contains some irrelevant parts (for example, the eyelid, sclera, and pupil), which cause significant degradation of the matching performance. The preprocessing step is designed to remove these irrelevant parts correctly from the given image and to extract only the iris region. In addition, the size of the extracted iris varies, depending on the camera to eye distance. So iris image should be normalized before the matching operation. Normalized iris image may contain some portion of eyelid. So this eyelid must be masked. Then we get normalized iris image with masked eyelid. And finally contrast enhancement is done on the obtained iris image. The Fig. 1 shows various steps of preprocessing stage. The preprocessing stage contains following steps:

- IRIS Localization
- IRIS Normalization
- Eyelid Masking
- Contrast Enhancement

2.1 IRIS Localization

This step detects inner boundary (the boundary between the iris and the pupil) and the outer boundary (the boundary between the iris and the sclera) in the original gray-scale image [1]. The segmented iris has been shown in Fig. 1(b).

2.2 IRIS Normalization

The next step is to normalize the extracted iris region to compensate for the elastic deformations in iris texture. We unwrap the iris region to a normalized rectangular block with a fixed size. First we used only lower half portion of the iris region and performance is evaluated. Then performance is evaluated by considering lower half portion of the iris region and some portion present in upper half of iris region (as explained in section 5). The normalized iris region is as shown in Fig. 1(c).

2.3 Eyelid Masking

This process masks the irrelevant eyelid region in the normalized iris image. The method which is used to detect inner boundary, can be used to find boundary between iris and eyelid. The detected eyelid region is masked as shown Fig. 1(d).

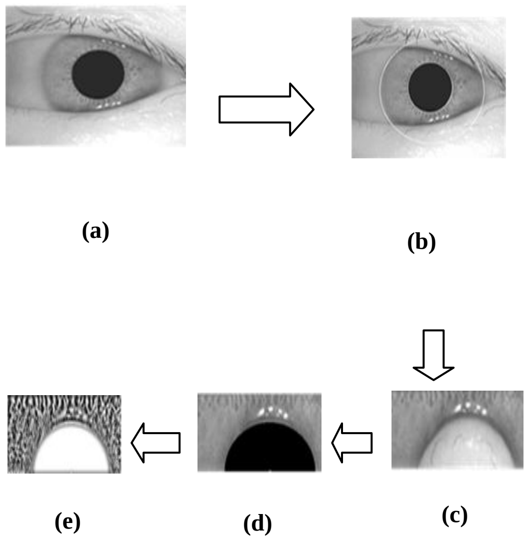

Fig 1: Iris image preprocessing (a) Original image (b)Detected inner and outer boundary (c) Normalized image (d) Normalized image with eyelid masking (e) Enhanced image

2.4 Contrast Enhancement

In some situations, the normalized iris image has low contrast. In such case, we improve the contrast by using local histogram equalization technique [11]. Fig. 1 (e) shows the enhanced image.

3. PHASE BASED IMAGE MATHCING

This section introduces idea of Phase Only Correlation (POC) function [1], [5], [6], [7], [8], [9]. In POC function, only phase components present in 2D DFT of images are used for comparison.

Consider two $N_1 \times N_2$ 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 $n_2=-M_2,\ldots,M_2$ ($M_2>0$) .

Also $N_1=2M_1+1$ and.$N_2=2M_2+1$. Let $F(k_1,k_2)$ and $G(k_1,k_2)$ be the 2D DFTs of the two images. $F(k_1,k_2)$ and $G(k_1,k_2)$ are given by

$$F(k_1,k_2) = \sum_{n_1=-M_1}^{M_1} \sum_{n_2=-M_2}^{M_2} f(n_1,n_2) W_{N_1}^{k_1 n_1} W_{N_2}^{k_2 n_2} \ldots\ldots\ldots\ldots(1)$$

$$G(k_1,k_2) = \sum_{n_1=-M_1}^{M_1} \sum_{n_2=-M_2}^{M_2} g(n_1,n_2) W_{N_1}^{k_1 n_1} W_{N_2}^{k_2 n_2} \ldots\ldots\ldots\ldots(2)$$

Where

$$N_1 = 2M_1 + 1 \text{ and } N_2 = 2M_2 + 1$$

$$W_{N_1} = e^{-j\frac{2\pi}{N_1}} \text{ and } W_{N_2} = e^{-j\frac{2\pi}{N_2}}$$

Then we calculate cross phase spectrum $RFG(k_1,k_2)$ as follow-

$$R_{FG}(k_1,k_2) = e^{j(\theta_F(k_1,k_2)-\theta_G(k_1,k_2))} \ldots\ldots\ldots\ldots(3)$$

Then POC function is given as

$$r_{fg}(n_1,n_2) = \frac{1}{N_1 N_2} \sum_{k_1=-M_1}^{M_1} \sum_{k_2=-M_2}^{M_2} R_{FG}(k_1,k_2) W_{N_1}^{-k_1 n_1} W_{N_2}^{-k_2 n_2}$$

$$\ldots\ldots\ldots\ldots(4)$$

When two images are similar there POC function $r_{fg}(n_1,n_2)$ gives 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.

The original POC function $r_{fg}(n_1,n_2)$ emphasizes the high-frequency components, which may have less reliability. This reduces the height of the correlation peak significantly, even if the given two iris images are captured from the same eye. On the other hand, the Band Limited POC (BLPOC) function [1], [6], [7], [8] allows us to evaluate the similarity by using the inherent frequency band of the iris texture. Assume that the ranges of the inherent frequency band of iris texture are given by $k_1= -K_1,\ldots,K_1$ and $k_2= -K_2,\ldots,K_2$ where $0 \le K_1 \le M_1$ and $0 \le K_2 \le M_2$. Thus, the effective size of frequency spectrum is given by $L_1=2K_1+1$ and $L_2=2K_2+1$.

The BLPOC function is defined as

$$r_{fg}^{K_1K_2}(n_1,n_2) = \frac{1}{L_1 L_2} \sum_{k_1=-K_1}^{K_1} \sum_{k_2=-K_2}^{K_2} R_{FG}(k_1,k_2) \times W_{L_1}^{-k_1 n_1} W_{L_2}^{-k_2 n_2}$$

$$\ldots\ldots\ldots\ldots(5)$$

Where $n_1 = -K_1,\ldots,K_1$ and $n_2 = -K_2,\ldots,K_2$.

4. MATCHING ALGORITHMS

There are two matching algorithms *i.e.*

- Baseline Algorithm
- Modified Algorithm

4.1 Baseline algorithm

Baseline algorithm contain following steps:

4.1.1 Effective region Extraction

Given a pair of normalized iris images $f_{norm}(n_1,n_2)$ and $g_{norm}(n_1,n_2)$ to be compared, the purpose of this process is to extract effective regions of the same size from the two images [1]. Let images after effective region extraction are $f_{eff}(n_1,n_2)$ and $g_{eff}(n_1,n_2)$.

4.1.2 Displacement Alignment

This step aligns the translational displacement (δ_1,δ_2) between the extracted images $f_{eff}(n_1,n_2)$ and $g_{eff}(n_1,n_2)$. The rotation of the camera, head tilt, and rotation of the eye within the eye socket may cause displacements in normalized images. The displacement (δ_1,δ_2) can be estimated from the peak location of the BLPOC function.

4.1.3 Matching Score Calculation

In this step, we calculate the BLPOC function between the aligned images $f(n_1,n_2)$ and $g(n_1,n_2)$. Then we evaluate the matching score. In the case of genuine matching, if the displacement between the two images is aligned, the correlation peak of the BLPOC function should appear at the origin $(n_1,n_2)=(0,0)$.

4.1.4 Precise Matching with Scale Correction

For some iris images, errors take place in the iris localization process. This error causes slight scaling in the horizontal direction (that is, the n1 direction) of the normalized iris image [1]. In the case of the genuine matching, this reduces the height of the correlation peak. Thus, if the matching score is close to the threshold value to separate genuine scores and impostor scores, we generate a set of slightly scaled images, calculate the matching scores for the generated images, and select their maximum value as the final matching score. In the case of genuine matching, the correlation peak value of the BLPOC function is enhanced. On the other hand, with impostor matching, there is no significant change in the peak value.

4.2 Modified Algorithm for degraded Iris Images

This section presents some modifications of the baseline matching algorithm which are especially suitable for degraded iris images. The baseline algorithm described in the previous section performs image matching only once. If the quality of iris images is sufficient, a single matching is enough to achieve highly accurate iris recognition. When the quality of iris images is significantly degraded due to, for example, defocusing and blurring, it is difficult to achieve high performance by the baseline algorithm. Addressing this problem, modified matching algorithm [1] can be introduced. Steps are given as follows:

4.2.1 Displacement Alignment

This process aligns the translational displacement (δ_1,δ_2) between $f_{norm}(n_1,n_2)$ and $g_{norm}(n_1,n_2)$. The displacement (δ_1,δ_2) can be estimated from the peak location of the BLPOC function.

4.2.2 Block Partitioning and Cross-Phase Spectrum Calculation

The aligned iris images $f_{norm}(n_1,n_2)$ and $g_{norm}(n_1,n_2)$ are partitioned into multiple (say N) blocks [1]. The BLPOC function is calculated for each block according to (5).

4.2.3 Block-Based Averaging of the BLPOC Function and Matching Score calculation

In this step, we calculate the weighted average of the BLPOC functions evaluated from all block pairs [1]. The weight w_i associated with the i^{th} BLPOC function is determined depending upon irrelevant pixels that belong to eyelid region [1]. If numbers of pixels belonging to iris region are more then weight of respective block will be more.

5. PROPOSED METHOD

The proposed method contains preprocessing stage and matching stage. The preprocessing stage of proposed method also includes steps like segmentation, normalization, eyelid masking and contrast enhancement.

The matching stage of proposed method is based on phase based image matching approach used by Kazuyuki et al [1]. The difference between our approach and approach used by Kazuyuki et al is related with portion of iris used for matching. Kazuyuki et al used only lower half part of iris for matching [1] as shown in Fig. 2

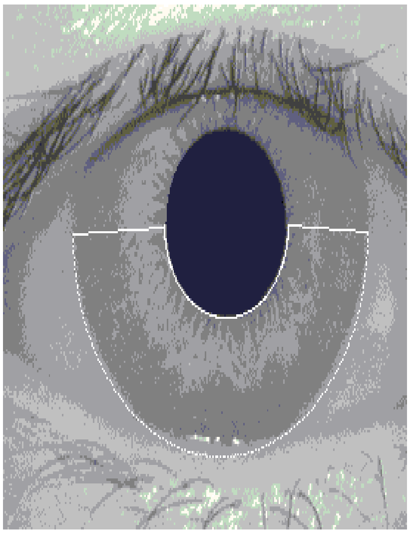

Fig 2: Lower half part of iris used by Kazuyuki et al

If we use only half part of iris then in some cases we get normalized images as shown in Fig. 3 where most of the part has been occupied by eyelid.

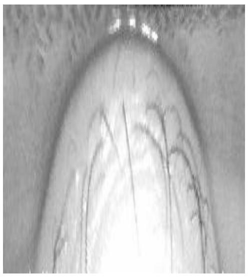

Fig 3: Normalized iris image whose large portion is covered by eyelid.

If we compare such iris image with other iris images in database then some false matches are observed as region available for comparison is very small. To overcome this problem, instead of considering only lower half part of iris we consider iris portion as shown in Fig. 4.

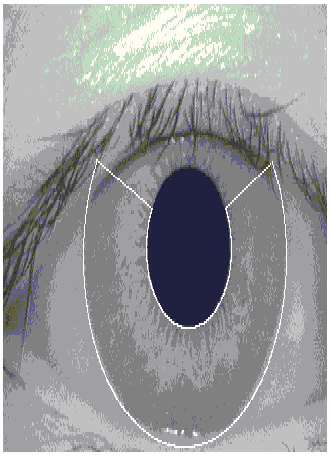

Fig 4:Eye image showing iris region selected for matching

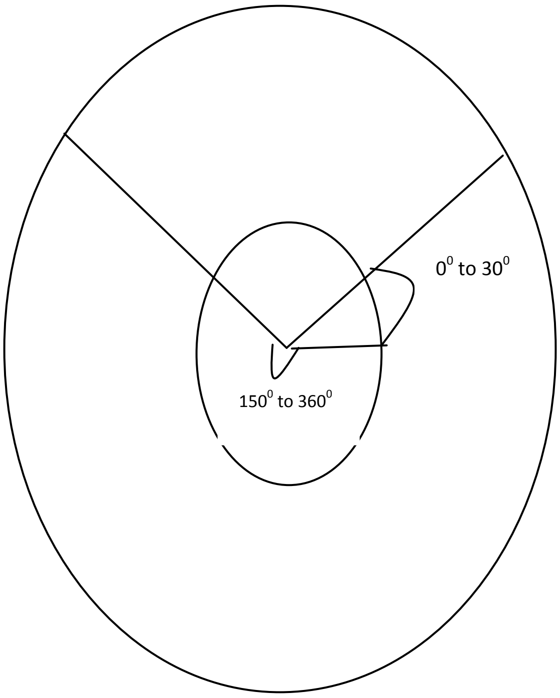

Fig 5: Portion of iris selected for matching

So here part of iris available for comparison increases. This approach does not affect False Non Match Rate (FNMR) but FMR decreases significantly. This decrease in FMR results in decrease in error rate. As shown in Fig. 5 iris region starting from 150^0 to 360^0 and starting from 0^0 to 30^0 is extracted. The iris region from 31^0 to 149^0 is not considered for matching as there is more possibility of having noise in this region.

6. EXPERIMENTS AND DISCUSSION

This section describes matching performance for both cases i.e. first case where only lower half part of iris (from $180^0$to 360^0) is used and second case where lower half part as well as some portion present in upper half part (from 150^0 to 360^0 and from 0^0 to 30^0) is used. Performance is evaluated using CASIA iris image database (version 1.0) [10]. CASIA iris image version 1.0 database contains 756 gray-scale eye images (320×280 pixels) with 108 unique eyes and 7 different images of each eye. CASIA version 1.0 is one of the most commonly used iris image database for performance evaluation and many papers contain experimental results on this database. So we used this database for evaluating performance of our algorithm. We first evaluate the genuine (intraclass) matching scores for all the possible combinations of genuine attempts. Next, we evaluate the impostor (interclass) matching scores for all of the possible combinations of impostor attempts. We used Receiver Operating Characteristic curve (ROC) and EER to evaluate the matching Performance. The ROC curve illustrates the False Non-Match Rate (FNMR, the probability that an authorized person is falsely rejected) against the False Match Rate (FMR, the probability that a non-authorized person is falsely accepted as an authorized person) at different thresholds on the matching score. EER indicates the error rate where FNMR and FMR are equal. We evaluate the error rates statistically by using the bootstrap technique [1]. Fig. 6 shows the ROC curve of baseline, modified algorithm for lower half iris region while Fig. 7 shows ROC curve for proposed approach. As observed in these figures, proposed method has very low EERs (0.002 for baseline and 0.00061 for modified algorithm).

If only lower half part of iris is considered for matching then many normalized iris images, obtained for CASIA version 1.0 iris database , has major part occupied by eyelid. So for such normalized images, portion of iris available for matching, is very less. For genuine matching, we get correct results but for imposter matching, obtained matching score exceeds threshold value. This increases FMR and as FMR increases, EER also increases. This is the problem in approach used by Kazuyuki et al [1]. The proposed method solves this problem by considering some portion of iris present in upper half part.

As shown in table 1, proposed method has very low error rate. Baseline algorithm for proposed method has EER 0.0020 while Modified algorithm for proposed method has EER 0.00061.

Table 1. Reported results on CASIA version 1.0

Method	EER
Baseline Algorithm [1]	0.029
Modified Algorithm [2]	0.019
Baseline Algorithm (Proposed Method)	0.0020
Modified Algorithm (Proposed Method)	0.00061

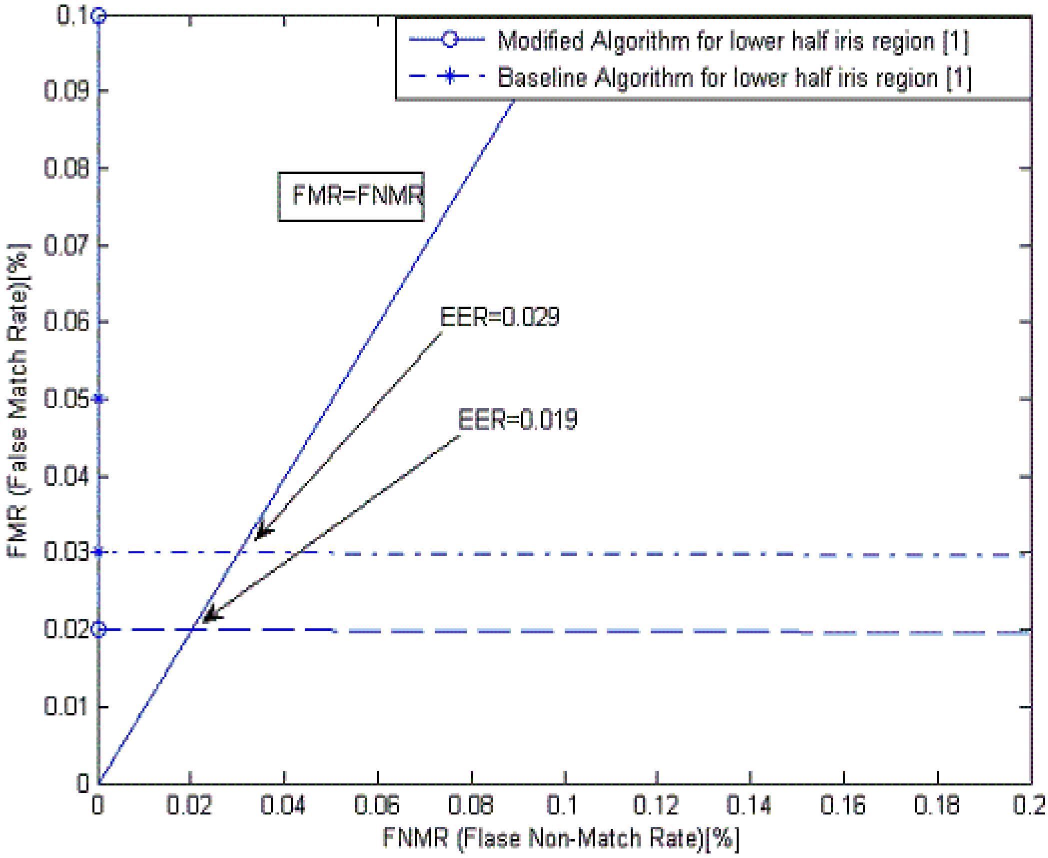

Fig 6: ROC curve and EER for only lower half iris region (CASIA iris image version 1.0 database)

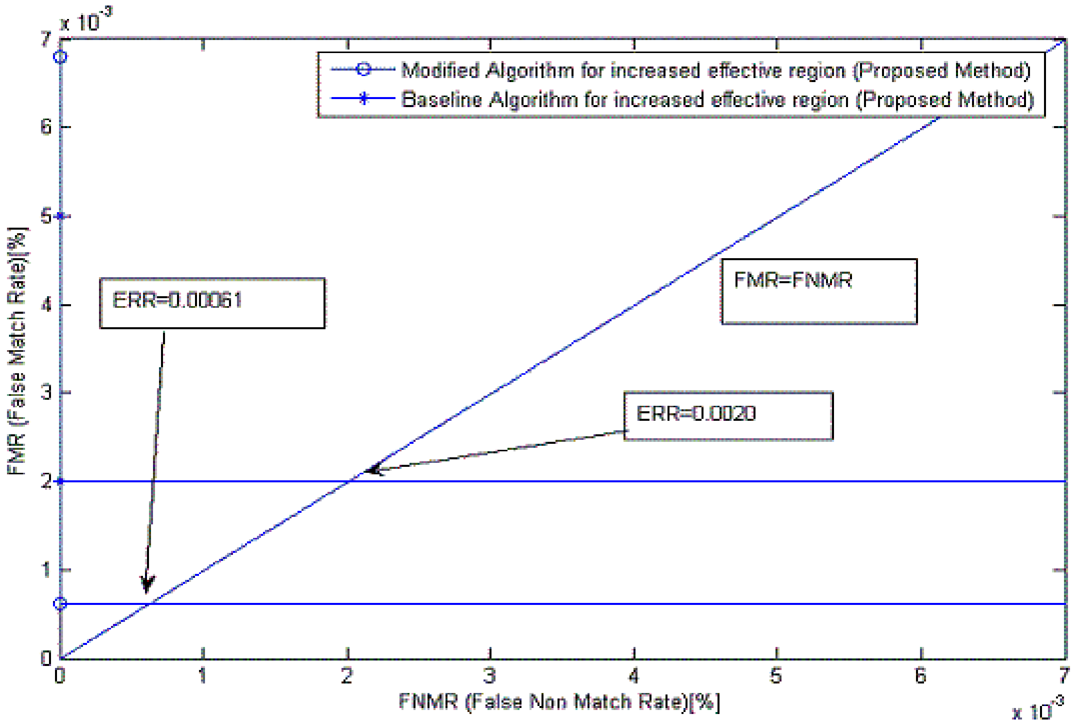

Fig 7: ROC curve and EER for increased effective iris region (CASIA iris image version 1.0 database)

7. CONCLUSION AND FUTURE SCOPE

The major contribution of this paper can be summarized as follow:

As we increased effective iris area, iris information available for matching increases. This increase in effective iris area is really good for the normalized images whose major part is occupied by eyelid. This approach does not affect FNMR but FMR decrease significantly. In this paper we used only some portion present in upper half part of iris (see section 5). If we use complete iris portion then we may get more accuracy. But upper half portion may contain irrelevant part such as eyelid and eyelashes. If we mask them then we can use upper portion of iris also. Detailed investigations in this direction are left for our future study.

8. ACKNOWLEDGMENT

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