An Offline Fuzzy Based Approach for Iris Recognition with Enhanced Feature Detection

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Abstract - **Among many biometric identification methods iris recognition is more attractive due to the unique features of the human eye [1]. There are many proposed algorithms for iris recognition. Although all these methods are based on the properties of the iris, they are subject to some limitations. In this research we attempt to develop an algorithm for iris recognition based on Fuzzy logic incorporated with not only the visible properties of the human iris but also considering the iris function. Visible features of the human iris such as pigment related features, features controlling the size of the pupil, visible rare anomalies, pigment frill and Collarette are considered [2]. This paper presents the algorithm we developed to recognize iris. A prototype system developed is also discussed.**

I. INTRODUCTION

Human identification (ID) plays a very important role in the fast moving world. Human ID is useful for authentication, person recognition, distinguishing personals and so forth. Fraud ID is one of the major problems in any part of the world. These frauds can lead to many disasters like unauthorized entry for terrorist act and so on. These factors have led researchers to find out more accurate, reliable and most importantly non-transferable or hard to fake human identification methods. As a result one of the amazing ideas has emerged by means of biometrics human identification.

When using biometrics for identifying humans, it offers some unique advantages. Biometrics can be used to identify you as you. Tokens, such as smart cards, magnetic stripe cards, photo ID cards, physical keys and so forth, can be lost, stolen, duplicated, or left at home. Passwords can be forgotten, shared, or observed. Moreover, in today's fast-paced electronic world, people more often asked to remember multitude of passwords and personal identification numbers (PINs) for computer accounts, bank automated teller machines, e-mail accounts, wireless phones, web sites and so forth. As a solution, Biometrics holds the promise of fast, easy-to-use, accurate, reliable, and less expensive authentication for a variety of applications.

There is no any perfect biometric that fits all needs. All biometric systems have their own advantages and disadvantages. The primary advantage of biometric authentication is that it provides more instances of authentication in such a quick and easy manner without

additional requirements. As biometric technologies mature and come into wide-scale commercial use, dealing with multiple levels of authentication or multiple instances of authentication will become less of a burden for users [3].

By definition "Biometrics is automated methods of identifying a person or verifying the identity of a person based on a physiological or behavioral characteristic" [3]. In other words, biometrics is to identify a person by using "Something that they have physically which cannot be changed" rather than "Something they know". For example fingerprint, iris, retina, face and voice are used rather than passwords, names or any other. In this research we use iris patterns of humans to ID each individual uniquely. What made our interest to do this research on iris recognition is the reliability and accuracy of iris patterns is overwhelmingly high due to the randomness of the iris pattern. Furthermore when compared to other biometrics the iris is less vulnerable to aging and external injuries because it is well protected by the anatomy of the eye.

Human eye is basically divided into two parts namely anterior chamber and interior chamber. It is separated by the iris and the lens which is vital and most important section of this research. The iris is a thin circular diaphragm which lies between the cornea and the lens in the direction of light entering in to the eye. When looked from the front of the eye, the iris is the pigmented area between pupil and the sclera. The iris have visible features like pigment related features, features controlling the size of the pupil, visible rare anomalies, pigment frills, crypts, radial furrows and Collarettes. These features of an individual are unique for that person. Hence our proposed system works based on above features to recognize an individual uniquely as these are the features that are mainly responsible for the randomness of the human iris pattern [2].

In this research work we attempted to develop an algorithm for iris recognition based on not only the main function of the human iris but also the outer appearance or visible features. A prototype system was developed based on the main function of the human iris and Artificial Intelligence (AI) techniques. In developing the system first we found a proper algorithm to extract important and essential feature of a human iris image. Secondly, as an AI technique, Fuzzy logic is applied for iris recognition and person identification. Finally a software

system is implemented to perform the above two tasks in order to demonstrate the system.

II. METHODOLOGY OVERVIEW AND USED MATERIALS

The system consists of two major phases. First phase is the enrollment (feature extraction) phase and the second phase is the verification & identification phase. In the first phase we detected the features of human iris[1] by using image processing methods. Then we extracted these features in a numeric (or digitized) format called iris code. In the second Phase we designed a fuzzy system which capable of accepting above iris codes as the crisp set input. The fuzzy system compares iris code of an individual with the iris codes from the enrolled iris code database to determine a match or mismatch. The architecture of the system is shown in Fig. 1.

The system is developed in Java programming language. In order to test the system an image database of 756 grayscale eye images are used. The grayscale iris images are collected from the Laboratory of Pattern Recognition (NLPR), Chinese Academy of Sciences, Institute of Automation (CASIA). CASIA Iris Image Database (version 1.0) includes 756 iris images from 108 eyes (hence 108 classes). According to CASIA for each eye, 7 images are captured in two sessions, where three samples are collected in the first session and four in the second session.

PERSON IDENTIFICATION

Identification of persons involves several steps: contrast stretching [4], pupil extraction, smoothing the image,

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1. It is considered that all the input images of the system are grayscale images and they should be in JPEG format.
2. The size of the input image is 320x280 pixels.

detecting the pupil boundary, restoring the original image, detecting the iris boundary, unrolling the iris [5], Gabor filtering [6], detecting features of the unrolled iris, extracting detected features and identification of person. Additionally an extra step is used for eyelashes and eyelids removal. The algorithm used to perform these tasks is described below.

A. Apply contrast stretching to enhance the image [4].

Contrast stretching ensures that the pupil fall in to very dark region of the eye image. This is a way of normalizing the image before processing. See Fig. 6 .

B. Extract the pupil boundary.

Since the early versions of pupil boundary detection algorithm failed in cases like the eye images with lot of eye lashes covering the pupil region. In order to solve this problem we applied the second form of contrast stretching as shown in Fig. 2 successively several times with different values of r_1 and r_2 where r_1 & r_2 are some arbitrary values each range from 0 to 255. The resulting image is shown in Fig. 7 . Equation (1) is used to calculate the new value of the pixel (nv) if old value of the pixel (old), minimum pixel value of the pixels in the image (min) and maximum pixel value of the pixels in the image (max) are known.

$$nv = 255 * (old - (min + r_1)) / ((max - r_2) - (min + r_1)) \quad (1)$$

Steps
1) First contrast stretch the resulting image of above step with $r_1=0$ and $r_2=10$
2) Repeat the contrast stretching with $r_1=200$ and $r_2=0$, then with $r_1=100$ and $r_2=0$, finally with $r_1=20$ and $r_2=0$
3) Now apply the contrast stretching three times in backward direction with $r_1=0$ and $r_2=200$
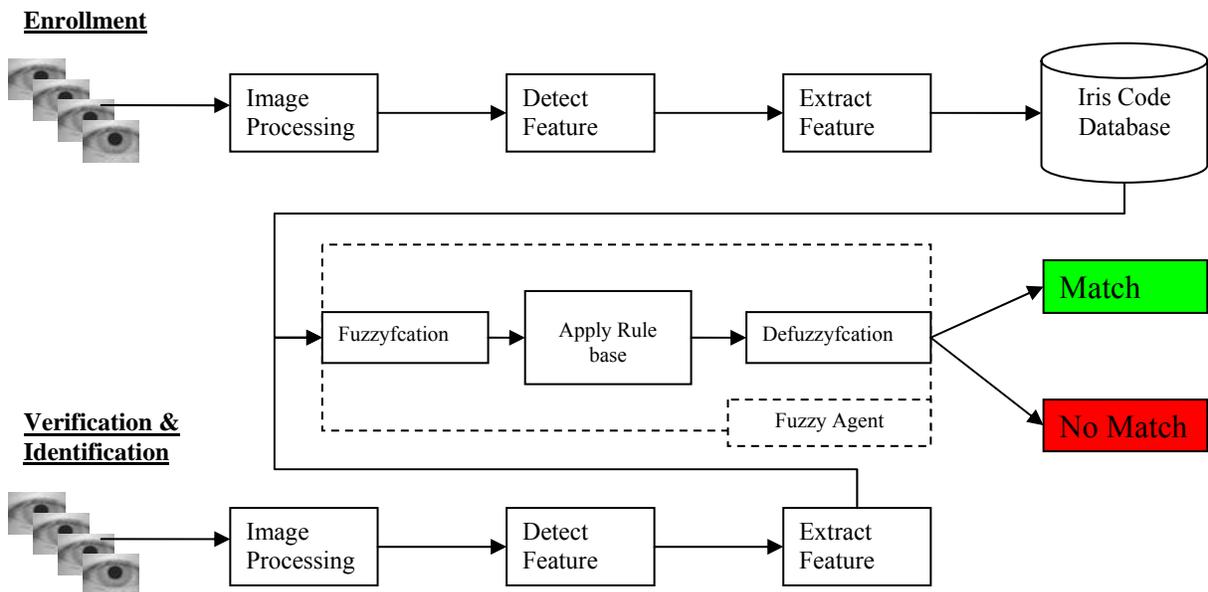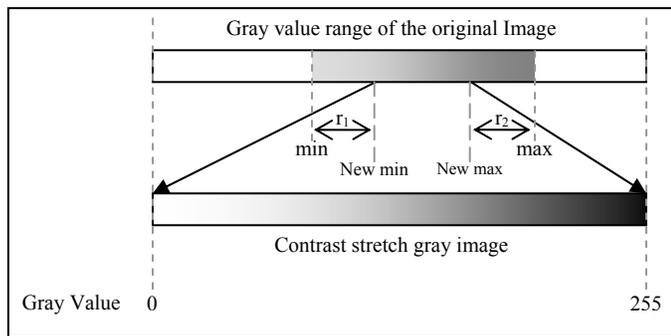

Fig. 1. The architecture of the system

Fig. 2 Second form of contrast stretching.

4) The dominant part of the resulting image would be the pupil region.

C. Smooth the image by applying a smooth filter with a 3 by 3 kernel.

Although the pupil boundary could be detected from the resultant image of the above step, the edge of the pupil is not smooth. This problem can be solved by applying a smooth filter as shown in Fig. 8 .

D. Detect the pupil boundary with the following algorithm.

Since the success of the person identification process heavily depends on the accuracy of detecting the pupil boundary, we put more emphasis on this step. As a result we outlined and used a new algorithm for this purpose. The algorithm is specified below. See the result in Fig. 9 .

Algorithm

Begin
   Find the maximum and minimum pixel grey values in the eye image.

   Set Threshold = (maximum grey value - minimum grey value) * 22%

   Iterate pixel by pixel from left-top corner to the right-bottom corner of the image.
      While traversing find what pixels falls under the threshold level.
      If (a pixel falls below the threshold) Then
         Check how many more pixels falls below the threshold just after that pixel contiguously in horizontal direction from left to right.
         Record that number of pixels and the coordinate of the starting pixel.
      End-If
   End-Iterate

   Using the above recorded values, find the longest horizontal stream of pixels which falls under the threshold and coordinate of the starting pixel.

   Again do the above iteration in the same direction and find the contiguous maximum number of pixels and its starting pixel coordinate that falls under the threshold in the vertical direction.

   Then repeat the above two approaches from bottom-right to top-left corner of the image and find another pair of longest horizontal and vertical contiguous stream of pixels which falls under the threshold value.

Finally average the middle points of the horizontal lines to get the x value of the pupil center and average the middle points of the vertical lines to get the y value of the pupil center.

Then average the half of the distance of all the 4 lines to get the radius of the pupil.
End

E. Restore the original image by loading the original image with the detected pupil boundary.

In this step the contrast stretched iris image with the pupil boundary was restored as shown in **Error! Reference source not found.**.

F. Detect the iris boundary using Dynamic Iris Boundary Detection algorithm.

For extracting the iris of an eye image, the pupil boundary alone is not sufficient. The outer boundary of the iris is also very important. Since most of the patterns of the iris rely near the pupillary area like radial furrows and pigment frills, it is not necessary to extract iris boundary as the actual iris boundary all the way up to Sclera from the pupil boundary. The use of a constant radius circular region from the pupil center, which includes only the vital features of the iris, is adequate in settling on the iris boundary. Sometimes the length of the radial furrows may get smaller or larger due to pupil dilation. It is important, therefore, to detect iris boundary such that length of the radial furrows in the detected iris region (i.e. the region between pupil boundary and iris boundary) for a same person should be same even the pupil has dilated. The radius of the iris boundary should change according to the size of the pupil. This part is tricky that, even though the iris boundary should be larger than the size of the pupil boundary, if the pupil boundary increased, the iris boundary should be reduced so that all the vital information of the iris will contained in between those boundaries (See Fig. 12). On the other hand iris boundary should expand if the pupil got smaller (See Fig. 11). To fulfill above phenomena we used equation (2) which calculated the iris boundary according to the size of the pupil.

$$NIrD = ((PD / 2) + 55 - ((PD / 2) * 2 / 100)) * 2 \qquad (2)$$

Where, NIrD is the new iris boundary diameter. PD is the diameter of the pupil.

G. Unrolled the iris into a 512x64 rectangular image [5].

The resultant image of the previous step is a radial image. In order to make the processing easier the rounded iris is unrolled to a rectangular 512x64 size image called "unrolled iris" image. The following existing algorithm is used to unroll the image. The resulting image is shown in Fig. 13.

Algorithm

Begin

Get the pupil center of the image.
Create a new unwrapped image with the default output image size.

Iterate over the Y values in the output image.
   Iterate over the X values in the output image.
      Determine the polar angle (ANG) to the current coordinate using the following formula:
         ANG = 2 * π * (X output image / width output image)   (3)
      Find the point that is to be 'mapped to' in the output image.

      Find the distance between the radius of the iris and the pupil.

      Compute the relative distance from the pupil radius to the 'map from' point.

      The point to map from is the point located along theta at the pupil radius plus the relative radius addition.

      Set the pixel in the output image at 'map to' with intensity in original image at 'map from'.
   Next X
Next Y
End

H. Apply the Gabor filtering [6].

To do the Gabor filter we applied the Gabor wavelet as explained in [6]. The interesting part is each iris has unique texture that is generated through a random process before birth. So this Gabor filter is based on Gabor wavelets turn out to be very good in detecting patterns in images. We have used a fixed frequency one dimension (1D) Gabor filter to look for patterns in the unrolled image. The algorithm is given below.

Algorithm

```
Begin
    Consider one pixel wide column from the unrolled image and
    convolve it with a 1D Gabor wavelet by using a 5x5 kernel.

    Since the Gabor filter is complex, the result will have two parts
    namely real and imaginary which are treated separately.

    // Then the real and imaginary parts are each quantized.
    If (a given value in the result vector > 0) Then
        Store 1
    Else
        Store 0
    Enf-If

    Once all the columns of the image have been filtered and
    quantized, a new black and white image will be formed by
    arranging all the resulting columns side by side.
End
```

For the parameters of the Gabor wavelet equation explained in [6], we have used following values:

$\mathbf{K}$ = 0.01
$\mathbf{(a, b)}$ = (1/50, 1/40)
θ = - π/2
$(\mathbf{x_0}, \mathbf{y_0})$ = (0, 0)
$(\mathbf{u_0}, \mathbf{v_0})$ = (0.1, 0.1)
$\mathbf{P}$ = π /2

These values are entirely arbitrary. These values are tuned such that most of the image details will be fall in the real part of the image rather than in the imaginary part so that it is enough to consider only the real part of the image. See Fig. 14.

I. Divide the unrolled image into 128x16 segments.

In this step the Gabor filtered real unrolled image with the size of 512x64 was divided into 128x16 segments. So the new image will look like in the Fig. 15 with 2048 small segments. Here each small segment holds 16 pixels.

J. Average the pixel values in each segment.

In the resultant image of the previous step, each segment has 4x4 pixels (i.e. 16 pixels) and it is a binary image with dark black pixels represented 1 and white pixels represent 0. If this is averaged there will be a value between 0 and 1 for each 4x4 segment. Since the image has 128x16 segments altogether there are 2048 segments in the image. Therefore we get altogether 2048 averaged segment values for an unrolled, Gabor filtered, real part of the iris image. Now this 2048 decimal valued string is unique code for this iris. So for each and every person this code is saved in the database.

K. Apply AI technique on these average pixel values to detect individuals.

We used Fuzzy Logic [7] to identify persons based on their iris code. For each matching, the iris is unrolled in different angels and applied the steps *J* through *K* to overcome the eye tilting in the image. That is, if the head of the person is tilted when the eye image is acquiring, there will be some amount of rotation with respect to iris images corresponding to the iris codes stored in the database. So the idea is to check the current iris code acquired with different rotation angles with the database iris codes. In the system it uses -7^0 to $+7^0$ angles. That is altogether 15 different rotations.

Agent and System
The system has one fuzzy input, one fuzzy output and the rule base.

Fuzzy Input
The crisp input of the fuzzy system is the magnitude of the difference between the iris code values corresponding to a particular segment of the matching iris code and the iris code from the database. For example, if the first segment value of the matching code is 0.75 and the first segment value of the iris code from the database is 0.65 then the crisp input of the fuzzy system is (0.75 – 0.65) = 0.1 . This crisp input is amplified by multiplying 100. Hence the input can range from -100 to +100 and the fuzzy input can be shown as follows;
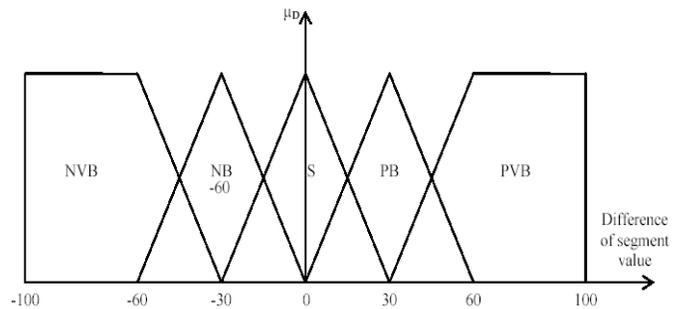

Fig. 3 Fuzzy input

NVB - Negative Very Big
NB - Negative Big
S - Small
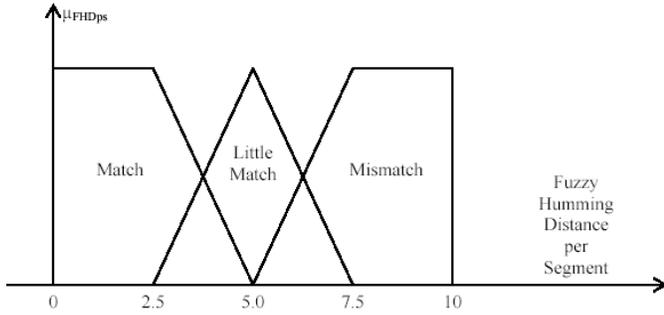PB - Positive Big
PVB - Positive Very Big

Fig. 4 Fuzzy output

Fuzzy Output

The fuzzy output of the system is called "Fuzzy Humming Distance per Segment" (FHDps). Fuzzy Humming Distance per Segment is the value which represents how close two segments of the two iris codes match each other. If the matching is high this value tend move towards zero. If the matching is very poor the FHDps will be large value which is close to 10. The fuzzy output is shown below.

Rule Base

The rule base is the knowledge of the system. The following rules base was created according to the simple domain knowledge.

IF Difference of segment values is 'Negative Very Big'
    THEN the Fuzzy Humming Distance per Segment is 'Mismatch'
IF Difference of segment values is 'Negative Big'
    THEN the Fuzzy Humming Distance per Segment is 'Little Match'
IF Difference of segment values is 'Small'
    THEN the Fuzzy Humming Distance per Segment is 'Match'
IF Difference of segment values is 'Positive Big'
    THEN the Fuzzy Humming Distance per Segment is 'Little Match'
IF Difference of segment values is 'Positive Very Big'
    THEN the Fuzzy Humming Distance per Segment is 'Mismatch'

This way the fuzzy system will give a crisp value of ranging from 0 to 10. This value is only for one segment. So to match two Iris Codes we checked pairs of all 2048 segment values. Then the output was obtained. That obtained all the crisp outputs which are greater than 5.0 were added together. In this way outputs less than 5 will not contribute to this addition. Finally this added value is divided by the number of segments checked. It's kind of taking the average of the added output. This added and divided value is I called "Fuzzy Humming Distance" (FHD). Fuzzy Humming Distance is the factor that used to match persons. This is somewhat similar to Hamming Distance (HD) in Dr. Daugman's approach [8]. But the difference between HD and FHD is that FHD is all based on the values of defuzzyfication.

    If the FHD is less than 1.5 then the checked iris images are 'Perfect Match'
    If the FHD is less than 2.5 then the checked iris images are 'Normal Match'
    If the FHD is less than 2.75 then the checked iris images are 'Low Match'
    If the FHD is greater than 2.75 then the checked iris images are 'No Match'
Now there is a tread off in 2.5 to 2.75 regions. If a person recognized in the confidence of a FHD value between 2.5 and 2.75 then there is a probability of misidentified.

The following sequence of images depicts the resultant images in applying the above described steps.
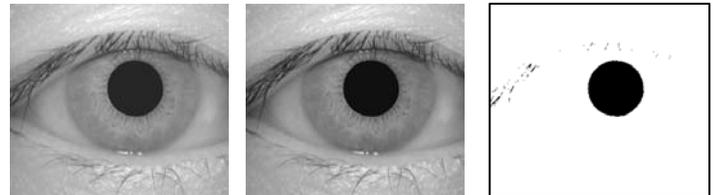

Fig. 12 The initial eye image

Fig. 10 Contrast stretched image
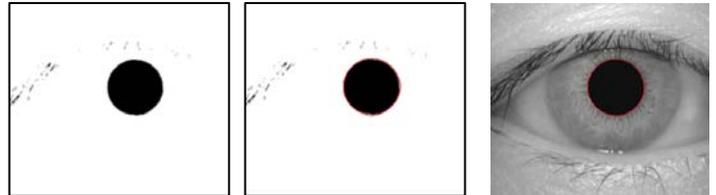

Fig. 11 Extracted pupil region

Fig. 6 Extracted pupil – smooth

Fig. 7 Detected pupil boundary

Fig. 5 Restored image with pupil boundary

Fig. 8 Dynamic iris boundary detection - sample of contracted pupil

Fig. 9 Dynamic iris boundary detection - sample of expanded pupil

Fig. 13 Unrolled iris

Real part

Imaginary part

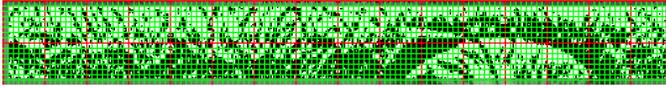Fig. 14 Gabor filtered unrolled iris

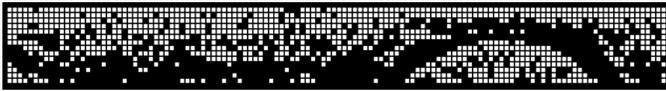Fig. 15 Gabor filtered, feature detected, real part of unrolled iris image

Fig. 16 Extracted features shown as a binary image

IV. RESULTS

Two tests were carried out with the CASIA image database. In that database, each person has 7 iris images which are divided in to two folders. One folder has 3 images and the other one has 4. In our test, we created a database of an iris code of all 108 individuals where it contained iris code for 3 eye images per person (using 3-image folder). The rest of the images (i.e. 4*108=432) were used to test the system. The number of unrecognized persons and misidentified persons was also computed.

A. Test 1

In this test the "dynamic iris boundary detection" and "eyelid and eyelash remover" were [9] not present. The test results were shown below. There was a bit of increase in unidentified percentage. To over come this, the algorithm was improved and tested in the second test.

Total checked: 420
False Match: 5
Unidentified: 32
Success count: 383
Success Percentage - 90.48%
Unidentified Percentage - 7.61%
False Match Percentage - 1.19%

We should also mention that this test took almost 7 ½ hours to process all 108 individuals. So it's a large time. This problem is also addressed in the next test.

B. Test 2

In this test the "dynamic iris boundary detection" and "eyelid and eyelash remover" [9] were applied where in [9] explains an accurate but complex algorithm to remove eye lid and eye lashes from an eye image. The test took 169 minutes 25 seconds for all 108 individuals. In this test the iris was rotated for angles -7^0 to $+7^0$ and checked for match. If not found then only the "eyelid and eye lashes remover" was applied and retested due to its time complexity. The test results were shown below.

Total checked: 432
False Match: 1
Unidentified: 5
Success count: 426
Success Percentage - 98.61%
Unidentified Percentage - 1.16%
False Match Percentage - 0.23%

The success percentage rose to 98.6%. The reason for misidentification and 1 false match may be due to the poor quality of the eye image such as very little visibility of the iris in the eye image.

V. CONCLUSION

In overall the final system was a very successful in recognition except very small number of mistakes. In the final test showed success rate of 98.6% with false accept rate (FAR) of 0.23% and false rejection rate (FRR) of 1.16% for 432 eye images checked with 324 trained iris coeds. Therefore, Fuzzy logic can be successfully applied to iris recognition.

FUTURE WORKS & SUGGESTIONS

Our whole intension was to find a more accurate algorithm for iris recognition using Fuzzy logic and enhanced feature detection. The results showed us our success. But we did not put our intention on the time complexities of the algorithms and more to the point it is not the scope of this research. There is plenty of room to enhance the algorithm on this section. Finally, we did our research based on offline images. So this work can be extended to recognize individuals using iris images in real time by making the system be able to cope with video streams instead of still images.

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