Fuzzy Clustering and Classification based Iris Recognition: A Medical Application

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Abstract: The Iris based authentication framework is basically a pattern recognition strategy that utilizes iris designs, which are factually unique. In this study, an efficient iris recognition system is developed with the help of Possibilistic Fuzzy C-Means Clustering (PFCM) and Fuzzy Logic classifier (FLC). The proposed methodology consists of four modules namely, pre-processing, segmentation, normalization and recognition. Initially, in the pre-processing module, the input images are adjusted to do further processing. Then, we segment the iris region from the input image with the help of PFCM. After that, the segmented image is normalized with the help of the Daugman Robber Sheet Model (DRS). Finally, the iris image is recognized with the help of FLC. The performance of the proposed methodology is analyzed in terms of different metrics namely, accuracy, false acceptance ratio (FAR) and false rejection ratio (FRR). Experimental results demonstrate, proposed PFCM+FLC method attains a better accuracy of 97.5%.

Keywords: Possibilistic fuzzy c-means clustering, fuzzy logic classifier, iris recognition, segmentation, and authentication.

1. Introduction

Biometrics is one of the significant thoughts for distinguishing people in various fields over the universe [1, 2]. This biometrics is delegated strengths for the acknowledgment of a human by different systems. Distinguishing or verifying one's uniqueness utilizing biometrics is broadly considered in this advanced robotized world, which is a significant reason for security issues in various territories. Biometrics is a delightful scientific automated identification that uses them to identify the sole physical or behavioral traits/characteristics of individuals. Since biometrics is fantastically difficult to manufacture and can't be forgotten or stolen, biometric authentication offers a supportive, exact, indispensable, and highly secure alternative for a person, which makes it have more inclinations over the ordinary cryptography-based authentication plans [3]. Probably the soonest exertion in biometric recognition in the United States was in 2001 by the Defense Advanced Research Program Agency (DARPA). Remote (human IT) anticipates needing to create advancements to distinguish, perceive, and recognize individuals over long separations [3]. Following the task, various research endeavors have been embraced on the gait [4, 5], face [6, 7] and iris [8, 9, 10]. Of all the biometric properties explored, the iris seems to show low false competition rates in huge databases acquired under controlled conditions.

Most researchers work in biometrics, specifically, because of its unique properties, such as, iris forms, which are unique and stable throughout the life of the individual. The protective organ of man is placed between the pupil and the sclera of the human eye. The iris system differs between the twins and the left and right eyes of a person. Iris biometrics has precise and reliable properties, which is why iris recognition systems are becoming more and more popular. The eyes capture images with data acquisition set under the standard lighting effects used for iris recognition. The iris step localizes the iris part of the image. The original eye image with the parts of iris, sclera, and pupil is given in figure 1. The inner circle

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is the papillary border (it placed between the iris and pupil). The outer circle is the limbic border (it is placed between the sclera and iris).

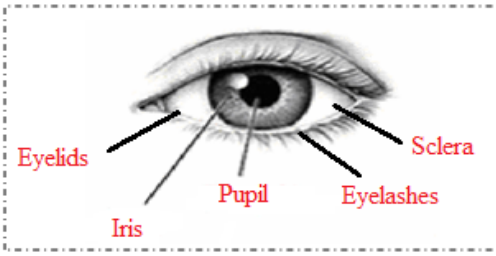

Figure 1: Original eye image

The iris usually has furrows, ridges and pigment spots. The central papillary zone and the outer ciliary zone are the two surfaces of the iris. The boundary of these two surfaces is the collarette. There is a difference between a person's left and right eyes [11]. Increasing the amount of pigment in the iris during childhood can change the color of the iris. However, for most human life, the origin of the iris is relatively stable.

2. Literature survey

A lot of researchers have been developed as an iris recognition system. Some of the works are analyzed here; Mamdouhi *et al.* [2] had explained the iris recognition system using an artificial neural network. Initially, the important attributes are separated from the iris image. Then selected attributes are given to the ANN classifier to classify an image as recognized or non-recognized. Here, to train the ANN, adaptive learning is utilized. This method was attained the maximum accuracy of 95%. Moreover, Dua *et al.* [13] had developed a radial basis function neural network (RBF-NN) based iris recognition. Here, the iris region is extracted from eyes with the help of circular Hough transform. Then, the DRS model is applied to normalize the iris image. After the normalization process, attributed are separated with the help of a log-Gabor filter. Then, the selected attributes are given to the RBF-NN to classify an iris image is recognized or not. Similarly, Subban *et al.* [14] had presented fuzzy particle swarm optimization based iris recognition. Here, for segmentation active contours are used. Then, haralick attributes are separated from each image. Then, important attributes are extracted with the help of particle swarm optimization. Then, selected attributes are given to the different classifiers and performances are analyzed.

Ahmadi and Neda [15] had developed morphological edge detection based human iris segmentation. Here, the local entropy of the greyscale image is used to compute the system images to extract the top and bottom structure. Then, the Otsu method is used to globalize the image threshold. Finally, the Haar bandwidth transformation is used for the feature extraction step. In [16], Ahmadi *et al.* had explained supervised machine learning algorithm based iris recognition. The radial basis function was utilized to recognize the iris image. Sinha *et al.* [17] had developed detecting fake iris from iris biometric. This system performance was analyzed in terms of security and reliability.

3. Proposed Iris recognition system

The iris-based authentication system is basically an identity recognition technique that uses iris forms, which are statistically unique, which are mainly used to identify individuals. In this study, the IRS is developed based on FLC. The proposed system consists of four stages namely, pre-processing, segmentation using PFCM, normalization using DRS, model and iris recognition using FLC. The overall structure of the proposed methodology is given in figure 2.

3.1 Image preprocessing

Initially, the images are collected from the database D. Then, the images are pre-processed. Pre-processing is an important process for iris recognition. The quality of the procured iris picture can be affected by numerous variables, for example, impediments, movement obscuring. Steps associated with

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pre-processing are optional and rely upon the picture acquisition conditions. It ought to be noted, thusly, that pre-processing of the iris shifts impressively between various frameworks. Ordinary pre-processing exercises incorporate eye location, picture quality appraisal, and picture upgrade. Picture quality appraisal decides if the info picture is deserving of ensuing processing (e.g., factors, for example, overwhelming iris impediment, huge scale reflection, can prompt dismissal of the information picture). Picture upgrades can be utilized to improve the quality of low-quality pictures utilizing basic methods, for example, histogram equalization or differentiation extending. Additionally, the filters are utilized to improve the nature of captured pictures.

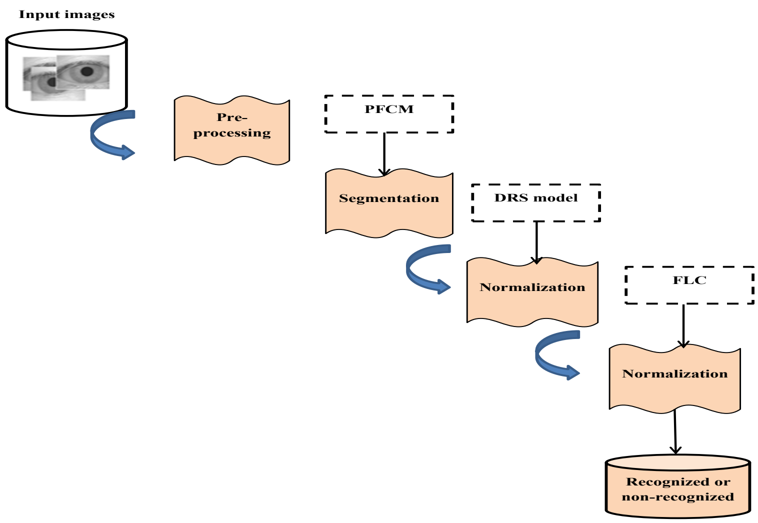

Figure 2: Overall concept of the iris recognition system

3.2 *Image segmentation using PFCM*

The reason for the iris segmentation stage is to localize the iris and pupil and to extricate the iris from the given image. This includes finding the inward fringe borderline the pupil, the little aperture, and the iris region and the outside borderline between the iris and the sclera, the white shaded piece of the eye. For segmenting iris region, in this chapter PFCM algorithm is utilized. PFCM is a clustering algorithm, which is utilized to group similar pixel based on a membership function. PFCM is a designed combination of PCM and FCM. This algorithm overcomes the difficulties present in the following clustering algorithms, namely, PCM, FCM, and FPCM. PFCM overcomes the problem of incidental clusters of the PCM, solves the noise sensitivity detection of the FCM, and distributes the sequence sum constraints of the FPCM.

Let us consider the input samples $Z = (z_1, z_2, ..., z_n)$. Then, based on the samples, m a number of clusters are formed $C = (c_1, c_2, ..., c_m)$. The objective function of PFCM can be written as follows;

$$O_{PFCM}(P,Q,R;Z) = \sum_{k=1}^{n}\sum_{i=1}^{c}(uP_{ik}^{m} + vQ_{ik}^{\eta}) \times \|z_k - r_i\|_A^2 + \sum_{i=1}^{c}\gamma_i \sum_{k=1}^{n}(1-Q_{ik})^{\eta} \tag{1}$$

Subject to the parameters $\sum_{i=1}^{c} P_{ik} = 1 \;\forall k$ and $0 \le P_{ik}, Q_{ik} \le 1$. Here $u > 0$, $b > 0$, $v > 1$ and $\eta > 1$. In (1) $\gamma_i > 0$ is the user-specified constant. The values u and v are constant. In this equation (1), Membership function P_{ik} is an important variable that is derived from the FCM. Based on equation (2), the P_{ik} is calculated which is given below;

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$$p_{ik} = \frac{1}{\sum_{j=1}^{c} \left(\frac{\|z_k - r_i\|}{\|z_k - r_j\|} \right)^{\frac{2}{m-1}}} \tag{2}$$

Likewise in equation (1), typically matrix T_{ik} is calculated from FCM. The Q_{ik} is calculated using equation (3).

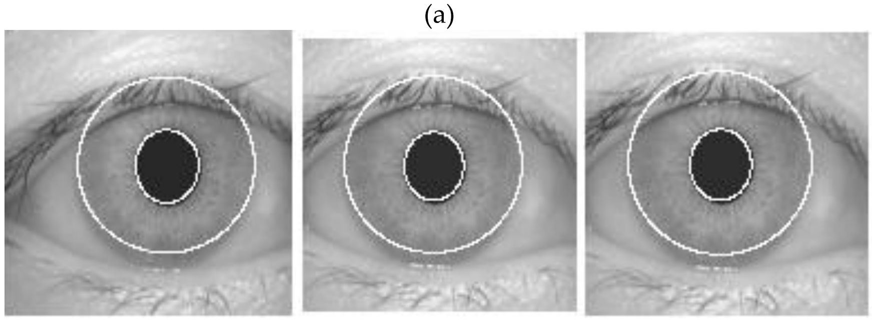
$$Q_{ik} = \frac{1}{1 + \left[\frac{D^2(z_k, r_i)}{\eta_i} \right]^{1/(m-1)}} \tag{3}$$

The cluster center Ri of PFCM is calculated as follows;

$$r_i = \frac{\sum_{k=1}^{n} \left(u p_{ik}^{m} + v q_{ik}^{\eta} \right) Y_k}{\sum_{k=1}^{n} \left(u p_{ik}^{m} + v q t_{ik}^{\eta} \right)}, 1 \le i \le c. \tag{4}$$

The clustering process continues on the iteration of the k-number. After the clustering process, the iris image $A(i,j)$ is segmented from the eyes image. The section results are given in Figure 3.

(a)



(b)

Figure 3: Segmentation output (a) input image and (b) segmented iris image

3.3 *Normalization*

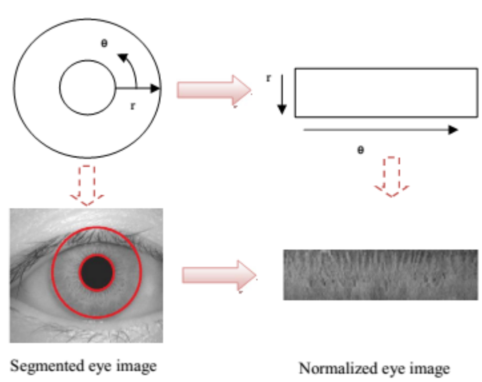


Figure 4: DRS Model

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After the iris region segmentation process, the extracted iris region is converted from ring shape to rectangle using a rubber sheet model. Basically, the DRS model [18] is used for the normalization process. The normalization process is given in Figure 4. On the polar axis, for every pixel in the iris, its proportional position is found. Two resolutions are available in this process: (i) radial resolution and (ii) angular resolution. Using the corresponding position, the iris position is converted to a 2D line by utilizing the flat components of the angular resolution and the vertical components of the radial resolution.

$$A[i(r,\theta), j(r,\theta)] \rightarrow A(r,\theta) \tag{5}$$

Where,

$A(i,j)$ → Iris region

(i,j) → Cartesian coordinates

(r,θ) → Normalized polar coordinates

Here, the θ value varies from $[0 \;\; 2\pi]$ and r value varies from $[0 \;\; 1]$. For the transformation function, the following formula is utilized.

$$i(r,\theta) = (1-r)i_p(\theta) + i_x(\theta)$$
$$j(r,\theta) = (1-r)j_p(\theta) + j_x(\theta)$$
$$i_p(\theta) = i_{p0}(\theta) + r_p Cos(\theta)$$
$$j_p(\theta) = j_{p0}(\theta) + r_p Sin(\theta)$$
$$i_x(\theta) = i_{x0}(\theta) + r_i Cos(\theta)$$
$$j_x(\theta) = j_{x0}(\theta) + r_i Sin(\theta)$$

Where,

(i_p, j_p) → Coordinates on the pupil boundary

(i_x, j_x) → Coordinates on the pupil iris boundaries

(i_{p0}, j_{p0}) → Center of the pupil

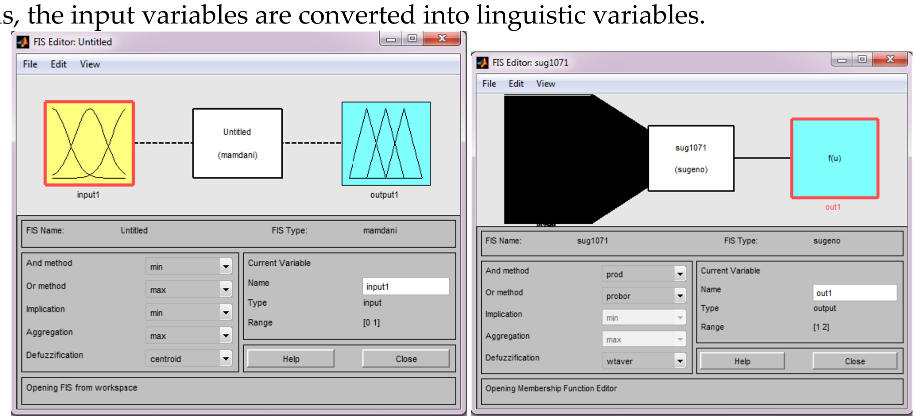
(i_{x0}, i_{x0}) → Centers of the iris center

3.4 *Iris recognition using FLC:*

The extracted features are given to the FLC to classify an image as recognized or non-recognized. The classifier consists of two phases, namely, training and testing. Initially, 80% of images are training using the classifier. After the training process, the new image is given to the classier. Based on the training process, the classifier has identified, the given image is recognized or non-recognized. For the recognition process, the FLC classifier is utilized.

Membership function

In FLC, Membership function is an important process. For this, in this study, subtractive clustering is utilized. In this, the input variables are converted into linguistic variables.



(a) (b)

Figure 5: Input (a) and output of the membership function (b)

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The linguistic variables are low (L), High (H) and medium (M).The input and output membership function is given in figure 5.

Rule base:

From the subtractive clustering, fuzzy rules are generated. Based on the linguistic variables fuzzy rules are generated. In this study, two classes are utilized namely, recognized image or non-recognized image. If the image is recognized means, the system got the output is yes, otherwise it produces no. The sample rules are listed below;

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Rule 1: IF (A1 is L) and (A2 is H) and (A3 is M) and (A4 is H) and . . . . (AN is L)
THEN output =Yes (Recognized).
Rule 2: IF (A1 is H) and (A2 is L) and (A3 is H) and (A4 is M) and . . . . (AN is H)
THEN output =No (Non-Recognized).
Rule n: IF (A1 is M) and (A2 is H) and (A3 is L) and (A4 is L) and . . . . (AN is M)
THEN output =Yes (Recognized).
Where;
R1-Rk→ The fuzzy rules,
A1-AN→ input feature of the rectangular array with size 1×N
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Recognition

After the training process, the input images are tested. In this study, 20% of the images are utilized for the testing process. During the testing process, the iris is recognized. Initially, testing images T_S are given to the FLC. The images are given to the Fuzzification and given the output score. Based on the score values, the images are recognized.

4. Result and Discussion

The proposed PFCM+FLC based iris recognition system experimental results are analyzed in this section. The proposed methodology is implemented in the MATLAB version (7.12). For experimentation, the CASIA dataset is utilized. The experimental used sample images are listed in figure 6.

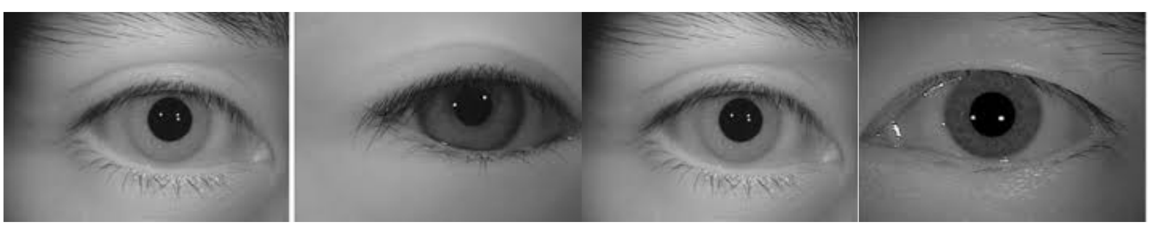

Figure 6: Experimental used sample images

4.1 *Evaluation metrics*

In this study, the performance of the proposed methodology is analyzed in terms of different metrics namely, Accuracy, FAR and FRR.

Accuracy: -The accuracy is the measured ratio between the total number of correctly recognized images and the total number of images.

$$Accuracy = \frac{TN + TP}{(TN + TP + FN + FP)}$$

Where FP represents the False positive, TP represents the True positive, TN represents the True negative, and FN represents the False-negative.

FAR: FAR is the probability rate at which quantities of Iris pictures are incorrectly gotten as "non-match".

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FRR: FRR is the probability rate at which the quantities of iris pictures are wrongly gotten as Match.

4.2 Experimental results

The main objective of this chapter is to effectively recognize the iris image with the help of the FLC and PFCM algorithm. To prove the effectiveness of the proposed methodology, the proposed method compared with different methods namely, PFCM+ANN, PFCM+SVM, and PFCM+KNN.

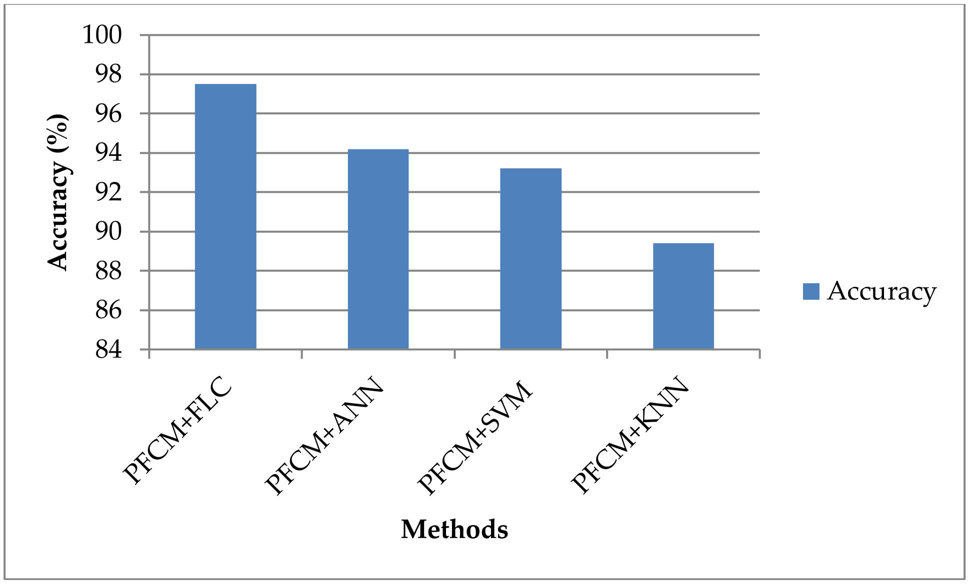

Figure 7: Performance analysis based on accuracy measure

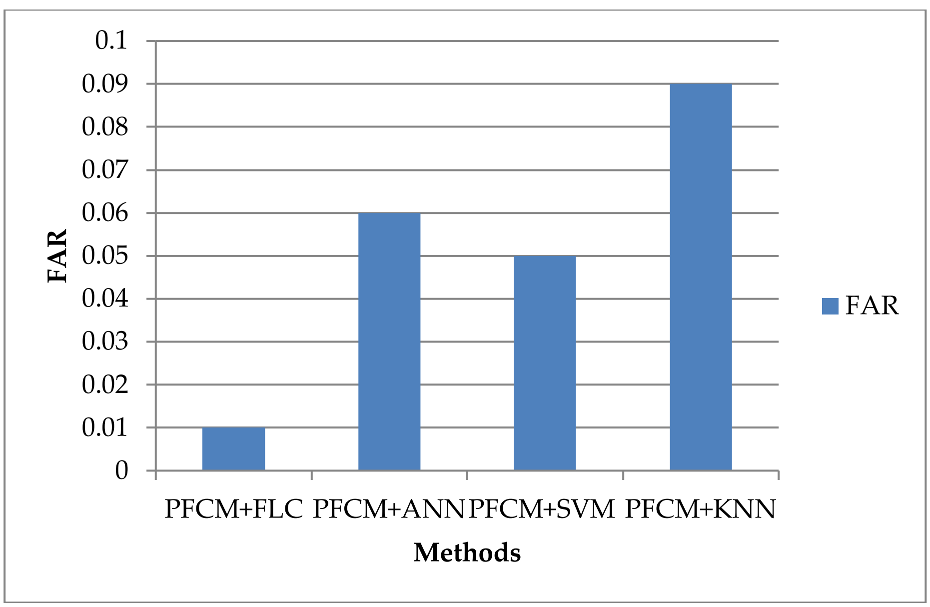

Figure 8: Performance analysis based on the FAR measure

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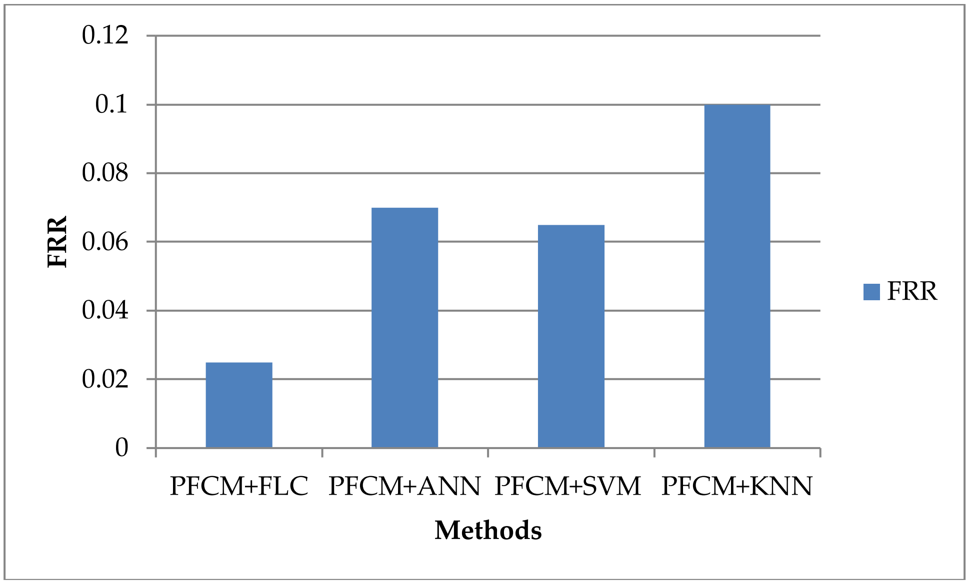

Figure 9: Performance analysis based on FRR measure

In Figure 6, the performance of the proposed method is analyzed based on the accuracy measurement. When analyzing Figure 7, our proposed PFCM + FLC based iris recognition system achieves a maximum accuracy of 97.5%, 94.2% for using PFCM + ANN-based iris recognition, 93.2% for using PFCM + SVM based iris authentication, and 89.4 for using PFCM. % + KNN based iris authentication. In Figure 8, the performance of the proposed method is analyzed based on the FAR scale. Here, the x-axis represents different methods and the y-axis represents FAR. When analyzing figure 8, the proposed method achieves a minimum FAR of 0.01, which is 0.06 for PFCM + ANN-based iris recognition, 0.05 for PFCM + ANN-based iris recognition, and 0.09 for PFCM + KNN-based iris recognition. The minimum FAR value yields the best recognition rate. In Figure 9, the performance of the proposed method is analyzed based on the FRR scale. Here, too, the proposed method achieves a minimum FRR of 0.025, which is lower, compared to other methods. From the results, it is clearly understood that the proposed method achieves better results compared to other methods.

5. Conclusion

The purpose of this research is to demonstrate the iris image segmentation and recognition. Here, the PFCM algorithm for segmentation is used and FLC for the classification process. Here, initially, the iris image is divided. Then, the image is converted to rectangular coordinates with the help of the TRS model. Then, the generated code is applied to the FLC to identify the iris image using ambiguous terms. The CASIA dataset is used for experimental analysis. The experimental results demonstrate that the proposed method of the PFCM + FLC framework performs better with a better accuracy of 97.5%.

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