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An Improved Biometric Fusion System Based on Fingerprint and Face using Optimized Artificial Neural Network

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Abstract: This research presents an improved biometric fusion system (IBFS) that integrates fingerprint and face as a subsystem. Two authentication systems, namely, Improved Fingerprint Recognition System (IFPRS) and Improved Face Recognition System (IFRS), are introduced respectively. For both, Atmospheric Light Adjustment (ALA) algorithm is used as an image quality enhancement technique for the improvement in visualization of acquired fingerprint and face data. Genetic Algorithm (GA) is used as an optimization algorithm with minutiae feature for IFPRS and Speed Up Robust Feature (SURF) for IFRS. Artificial Neural Network (ANN) is used as a classifier for IBFS. For the demonstration of the results, quality based parameters are computed, and in the end, a comparison is drawn to depict the efficiency of the work.The optimization techniques such as Particle Swarm Optimization (PSO) and BFO (Bacterial Foraging Optimization) has been considered to determine the effectiveness of the proposed model.The experimental results consider different parameters such as False Acceptance Rate (FAR), False Rejection Ratio (FRR), Accuracy and Execution time which shows that performance of the proposed model better than the other optimization models. In addition, to enhance robustness of the proposed structure, the results further compared with conventional technique which shows that accuracy has been improved by 2%.

Index Terms: Biometric Fusion, Face recognition, Fingerprint recognition, Feature Extraction, Feature Optimization, Classifier.

I. INTRODUCTION

The main reason for not executing the uni-modal biometric recognition system in security system apart from minimalistic security measures and smartphone lock screen is the unreliability of the system [1]. Most of the security systems are based on fingerprint, face, iris, palm and so on, but because of its nature (uni-modal), the chances of un-authenticity in uni-modal is more, and there is a need to design a multi-modal biometric system based on the fusion concept. The number of researchers has already implemented the face and fingerprint-based fusion system, but due to the presence of distorted input data (fingerprint and face images), the classification accuracy is not up to the mark [2].Therefore, in this work, a new biometric system is proposed that overcomes the authenticity problem by using a combination of faces and fingerprint traits[3].

The organization of the paper is as follows: Section 2 defines the existing work in fingerprint and face biometric traits in the form of related work — section 3 frames the established multimodal fusion system. In Section 4, experimental results are described in the considered case, and Section 5 concludes the work.

II. RELATED WORK

Researche shave proposed a novel joint density distribution based on rank score fusion that integrates score and rank information. The researchers have created a new soft biometric database with a body, human face with clothing attributes at three different distances for investigating the indirect influence on the soft biometric fusion. The evaluation is made on the soft biometric database [1]. Scholarshas recognized SBB (Social, behavioral behavior) features from online social information and has presented an architecture for utilizing the features employing automated person recognition preliminary. The results on semi-real and virtual databases have demonstrated considerable performance gain as compared to the existing biometric system [2]. Practitioners have provided varied feature types for every sensing modality with the relationship to biomechanics and the appearance of gait. The authors have specified the problems and challenges in gait recognition [3]. Scholars has proposed a multi-biometric system that fuses palm dorsal vein, slap fingerprints with hand geometry for proper person authentication. The outcome has indicated that authentication with slap fingerprints could be enhanced by considering the IR hand images knowledge [4].Researchershave presented two level score level fusion method for an amalgamation of the scores being obtained from the concealable template of various biometric characteristics. The analysis has been executed on two virtual databases and has been contrasted with the traditional density, classification, and existing score fusion methods. The results have shown that the proposed methods have improved the performance than the uni-biometric system by fulfilling the secure authentication requirement [5].

III. THE ESTABLISHED MULTIMODAL FUSION SYSTEM

This segment of the research describes the architecture of the proposed biometric system based on fingerprint and face [6].

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The databases for the simulation of the proposed work, the framework of improved biometric fusion system, Improved Fingerprint Recognition System, Improved Face Recognition System as described by the researchers .

A. A framework of the improved biometric fusion system

The multimodal biometric system is a substitute that improves the regular performance of a biometric system based on the quality improvement technique for input data. The image quality improvement based multimodal biometric system is known as an improved biometric fusion system (IBFS). In IBFS, information understanding can occur at the feature levels and the matching phase, score level is generated by multiple classifiers about differentiate the category at the decision level [6].

IBFS is a score level of fusion architecture. Since the feature set contains more information about the input biometric data than the matching score or the output decision of a matcher, fusion at the feature level is expected to provide better recognition results, and it is dependent on the pre-processing of input data. However, pre-processing is a difficult task to achieve a better quality of input image for biometric system. This paper aims to propose a new approach to increase the accuracy of IBFS and to reduce the insufficient accuracy of biometric traits, which is created by noisy data, using fusion levels algorithms between fingerprints and face recognition system [7].

The first system is based on fingerprint verification using the combination of Atmospheric Light Adjustment (ALA) for image enhancement technique with Genetic Algorithm (GA) based minutiae feature extraction technique and artificial neural network (ANN) for classification. The second system is based on face verification using GA based Speed up Robust Feature (SURF) extraction technique with ANN. In this work, fingerprint, and face biometric traits are considered because a biometric recognition system based on fingerprint looks for specific characteristics in the linear pattern on the plane of the finger. The edge of the line connected and the pattern of line form the fingerprint image to get recognized. So we can say that fingerprint biometric is already familiar to much of the communal and is therefore accepted by a large number of users. To fuse fingerprint and face at score level, strategies such as the simple average, sum, minimum and maximum of a score are used but in the proposed work feature based score level fusion is adopted.

B. Improved Fingerprint Recognition System (IFPRS)

Fingerprint recognition is one of the oldest and most prestigious research areas in the field of pattern recognition, but several researchers have faced lots of problems due to unmannered data collection.Out of these biometric trait, a fingerprint is widely accepted for person identification because of its uniqueness and immutability nature [8].

It is widely used in access control for the commercial and residential application, for time and attendance system. Fingerprint image can be produced either by offline or online, in the offline method; fingerprint image is obtained by impressed, inked fingertip on a paper, which is then scanned to the computer while in online technique, the fingerprint image is produced when a finger is impressed against a biometric sensor that is connected to a computer. So, in this procedure, a lot of noise and irrelevant data is added in the fingerprint images and this research, this problem is overcome by using pre-processing, feature extraction and optimization technique with classifiers [9].

C. Pre-processing of the fingerprint image

Image pre-processing may have impressive positive effects on the quality of feature extraction and the results of image analysis [10]. Fingerprint image pre-processing is equivalent to the mathematical normalization of a fingerprint, which is a natural step in many feature extraction method. The pre-processing steps which are applied on uploaded fingerprint images to generate compatible fingerprint data for proposed work are given as:

2.Color conversion: Color conversion is applied to the upload fingerprint image to find out their luminance, which helps in the minutiae extraction process [11].

$$GrayImage = 0.299 \times R_b + 0.587 \times G_b + 0.114 \times B_b \quad (1)$$

Where, Rb: Red Component of an image

G_b: Green component of an image

B_b: Blue component of an image

Image enhancement:Image enhancement is used to improve the specific pixel points of an image, rather than fix problems. In the IFPRS, ALA image enhancement technique is used to improve the quality of fingerprint which helps to find out the exact minutiae feature of a fingerprint. The ALA algorithm is given as:

Algorithm 1: ALA Algorithm

Input: Gimg→Gray Image

Output: Eimg→Enhanced Image

I=double (Gimg)

[Height, Width, Plane] = size of I

Patch Size = 15// Image parts considered

Pad Size = 7//Extra Boundary added

Pmat = Pad array (I, [Pad Size, Pad Size]) // It is blank mask according to the Pad Size

for j → 1 to Height

for i→ 1to Width

$$Patch = Pmat(j:(j + PatchSize - 1), i:(i + patchSize - 1), All) \quad (2)$$

$$Zmat(j,i) = min(Patch(:)) \quad (3)$$

end

end

A= atmLight (double (I), Zmat, Plane) // Apply Atmospheric Light Adjustment

Oimg=1-Zmat

Eimg = zeros (size (I)) // Blank matrix with size of I

For ind→ 1to Plane

$$Eimg(All\ rows, All\ Columns, ind) = A(ind) + (I(:,:,ind) - A(ind))./max(Oimg, 0.1) \quad (4)$$

Where 0.1 is lightning coefficient

end

return: Eimg as an enhanced image

end

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D. Fingerprint Feature optimization

Feature optimization is also known as feature selection or attributes selection in the pattern recognition system. Feature optimization is different from dimensionality reduction technique [12]. Both methods seek to reduce the number of the feature in the dataset, but a dimensionality reduction method creates new combinations of the feature, whereas feature optimization methods include and excludes the feature present in the data without changing them. In this research, GA is used as a feature optimization technique, and the algorithm of GA is given as:

Algorithm 2: Genetic Algorithm
Input: FP →Feature points
Output: OFP → Optimized feature points

Initialize GA parameters – Iterations (T)
– Population Size (P)
– Crossover function
– Mutation function
– Fitness function (F(t))
– Selection function ($fs and ft$)
Calculate T = Size (Input)

Fitness function: $$f(fit) = \begin{cases} 1, & fs < ft \\ 0, & fs \geq ft \end{cases} \quad (7)$$
for→ T
$$fs = \sum_{i=1}^{P} f(i) \quad (8)$$
$$ft = \frac{\sum_{i=1}^{P} f(i)}{Length of feature} \quad (9)$$
$f(fit)$ = fitness function which defines by equation (7)
$No. of\ variables = 1$
$No. of\ variables = 1$
$Opt_{value} = GA(f(fit), No. of\ variables, Initialize\ parameters)$
end
while T ~= Maximum
$Optimized\ data = Opt_{value}$
return; Optimized data as a set of optimized feature points
end

GA reduces the feature count by approximately 20 %. A total count of 500 images was considered as the dataset and a total feature vector of 350 elements are extracted. GA successfully demolishes around 20-30 features of each image. Hence the input set to Genetic Algorithm is 500*300, and the optimized set is 500*270.

E. Improved Face Recognition System (IFRS)

Face recognition is the main step for this research because it contributes to the greatest part of the IBFS. To recognize a face, following approach (see fig.1) is used, because the face is completely a complex multidimensional structure. So, there is a need to compute better recognition techniques with enhanced input data [13]. Therefore, in this research, the complexity problem is overcome by using pre-processing, feature extraction, and optimization technique with classifiers. The architecture of the IFRS is shown in fig.1.

Pre-processing of the face image

Face data acquisition (FDAQ) is the process of uploading the captured face images for further processing in IBFS. An FDAQ system is dependent on the size of captured face data by a camera during capturing process. The algorithm of FDAQ is similar to FPDAQ [14].

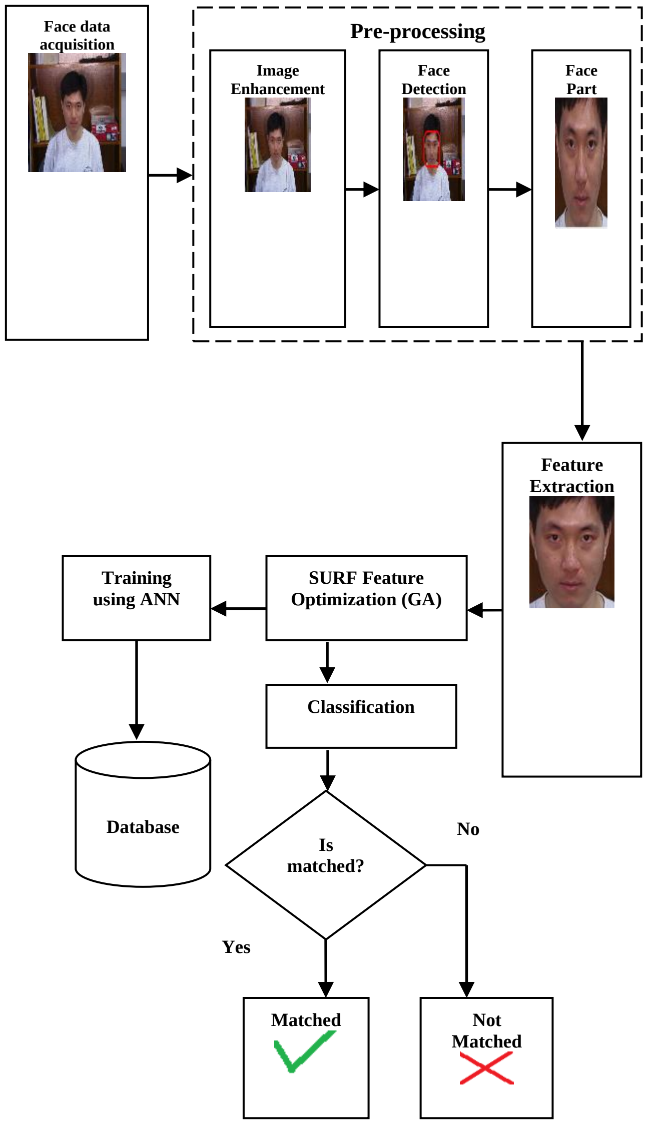

Fig.1 IFRS Architecture

In IFRS, pre-processing steps are used to extract the region of interest (ROI), which helps to find out the exact face region from the uploaded image. The used pre-processing algorithm is given as:

Algorithm 3: Pre-Processing Algorithm for IFRS
Input: Fimg→ Upload face image
Output: PFimg→ Pre-processed face image
Apply pre-processing algorithm on an uploaded face image
for i → 1 to all sets
Resize image = Resize (I) // Used to resize the image
Face detection = Face detector (I)
Threshold = Threshold (Face detection)
Gray Face = Gray conversion (Face detection, Threshold)
ROI = Crop (Gray Face, Region of Face)// Use to select region of Interest for face images
end
return: ROI as pre-processed image
end

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Based on the above-mentioned procedure in IFRS, we obtained pre-processed face image ROI, which show in fig.2. The pre-processing of face image such as (a) Original face image (b) Enhanced face image (c) Face detection from an enhanced image and (d) ROI of a face image. After the pre-processing, the SURF feature extraction technique is applied to the ROI of the face image.

Fig.2 Pre-processing of face

F. SURF extraction of a face image

The intention of minutiae extraction is to identify the diplomat features known as minutiae and to extract them from the enhanced thin fingerprint images. It is a very complicated task to opt for the important and accurate minutiae point from input images. The SURF feature point's for the extraction algorithm of proposed work is given as:

Algorithm 4: SURF Algorithm

Input: PFimg→ Pre-processed face image
Output: F points→ Feature points
Load ROI data of face images
for I = 1 to all sets
Extrema detection= PFimg (I)
Keypoint_localization=Extrema detection (I)
if localization need orientation
Orientation=Keypoint_localization (I)
end
Fpoints_descriptor=All best Feature
end
return: AF points as feature points
end

Fig.3 SURF features of face ROI

The SURF point of uploaded face image based on their ROI, which helps in training and classification of proposed IBFS is depicted in fig.3. In the fig, red color points represent the SURF points which are used as a set of features. After that, the SURF points are optimized, and the useful SURF points are discovered, which helps to train and test the proposed system.

G. Face Feature optimization

In IFRS, feature optimization is used to generate the unique feature sets from SURF feature points. In both IFPRS and IFRS, feature optimization is used similarly to optimize SURF points using GA, and the algorithm of GA is similar to IFPRS [15].

After the feature optimization in both sections, training of system is required for simulation of the system. For the training of proposed IBFS, ANN is used with an optimized feature set as training data, so it is called Optimized ANN.

The ordinal measures of ANN are as follows.

ANN is a three-layer architecture which has an input layer followed by the hidden layer and co followed by the output layer. The input layer takes the data along with its associated label. In the case of the proposed algorithm, the training data would be an optimized feature set. The input layer also contains the associated label of the input data. The associated label could be the specific identity of the data or anything through which the data can be identified. Here for each image which is passed for the feature extraction and processing, has a labeled name. For example, Feature set 1 is associated with a labeled name "Yohan." ANN is a multiclass classifier, and hence more than one image can be classified at once. This data can't be processed by neural network directly, and hence the ANN architecture changes the data into weights. The hidden layer propagates the data in the forwarding direction first and then cross-validates the data by going back through Mean Square Error. The proposed architecture utilized a neuron count ranging from 20-100 to process the data in the hidden layer. ANN has three types of propagation models as follows

i. Linear Model: The linear model propagates the data in the forward direction using the linear model only. The data is propagated using the following equation.
ii. Propagation Equation: $ax + b = 0$ where a and b are arbitrary constants.
iii. Quad Model: The Quad model uses s Quadratic propagation equation for the forward direction. The equation defines it $ax^2 + bx + c = 0$ a, b and c are arbitrary constants here.

The third propagation model is a polynomial propagation model which has an nth degree of propagation type. The losses are calculated using MSE itself.The ANN algorithm of the proposed work is given as:

Algorithm 5: AAN Algorithm

Input: Optimized feature sets as training data (T), Target (G) and Neurons (N)
Output: Trained Network Structure
Initialize ANN with parameters – Epochs (E)
– Neurons (N)
– Performance parameters: MSE, Gradient, Mutation and Validation Points
– Training Techniques: Levenberg Marquardt (Train lm)
– Data Division: Random
For i→ 1to T// loop executed for training data to create group
Group (i) = Categories of Training data
end

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Initialized the ANN using Training data and Group
Net = Newff (T, G, N)
Set the training parameters according to the requirements and train the system
Net = Train (Net, Training data, Group)
Return: Net as ANN Trained Structure
End

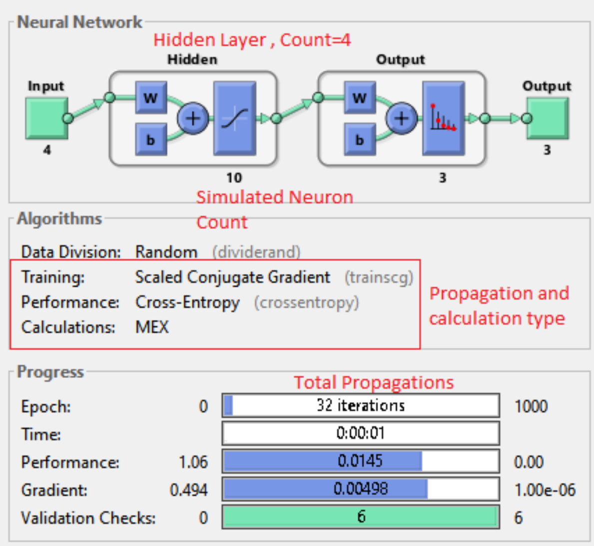

Fig. 4(a) Neural Propagation

Fig.4(a) demonstrates the working of ANN. Though a different number of neurons at hidden layers are tried, Fig.4 demonstrates the working of 10 neurons and 4 hidden data layers explicitly. The neural network is trained using a "Scaled Conjugate Gradient" training architecture. The cross-validation of the training is done through entropy calculation, which is the degree of disorder for neural networks. The graphical representation is done in Fig.4(b).

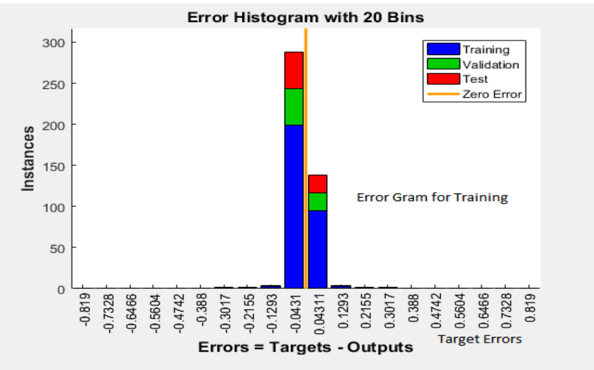

Fig.4(b) The error gram

H. Database used

Fig.5 represents the samples of the user database in proposed improved biometric fusion work based on the fingerprint and face. In the given Fig.1(a) the FVC fingerprints database, and 1(b) the Georgia Tech face database is represented. In any biometric recognition system, data collection is one of the most critical and time-consuming tasks. In the proposed work, the FVC database for simulation of the fingerprint recognition system is used.

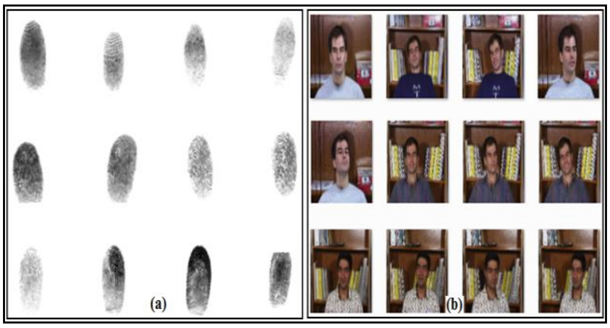

Fig.5Database (a) Fingerprint and (b) Face

A multi-database is formed with 10 fingerprints, and each fingerprint is collected with different sensor technology. The image format in the database is TIFF with 256 gray-levels, and all images are uncompressed. The fingerprint image size and resolution diverge dependent on the database images. The Georgia Tech face database contains total 50 face images taken in two or three sessions between Jun 01, 1999 and Nov 15, 1999, at the center for Image & Signal Processing at Georgia Institute of Technology. Users in the database are represented by 10 color JPEG images with the jumbled background taken at resolution 640x480 pixels. The average size of the faces in using database images is 150x150 pixels. The pictures have demonstrated front and twisted faces with different facial terms, lighting conditions, and scale.

I. Other Models proposed using Particle Swarm Optimization (PSO) and Bacterial Foraging Optimization (BFO)

This section highlights that the proposed model has been developed considering the PSO and BFO optimization techniques to check the effectiveness of optimization techniques for biometric fusion system. So, in this research, three different fusion models with GA, PSO and BFO as an optimization technique to select appropriate SURF feature for training artificial neural networks. The experimental results of the proposed model IBFS, PSO and BFO has been compared in section 4.

IV. EXPERIMENTAL RESULTS

The proposed IBFS has combined fingerprint recognition subsystem with face recognition subsystem. The training and testing of the proposed mechanism are evaluated by fingerprint and face database. By adapting the established proposed algorithms, below outcomes are computed with quality based parameters, such as False Acceptance Rate (FAR), False Rejection Ratio (FRR), Accuracy, and execution time.

- False Acceptance Ratio

It is also called Type 2 error. It is a measure which determines the unauthorized access to the system. In mathematical form, it is given as:-

$$FAR = \frac{False\ Acceptances}{Total\ number\ of\ attempts\ from\ uauthorized\ user}$$

- False Rejection Ratio

It is a measure of false or unauthorized users aces the system. It is also called Type 1 error.

$$FRR = \frac{Count\ of\ false\ rejection}{Total\ number\ of\ attempts\ from\ uauthorized\ user}$$

- Accuracy

It is defined as a measure of performance in terms of FAR and FRR. In mathematical form, it is expressed as:-

$$Accuracy = 100 - \frac{FAR + FRR}{2}$$

Table 1.Test results of the proposed IBFS with the other techniques for FAR and FRR

Itr	FAR			FRR		
	IBFS	PSO	BFO	IBFS	PSO	BFO
1	0.823	0.839	0.898	0.913	0.931	0.944
2	0.835	0.845	0.937	0.925	0.949	0.944
3	0.839	0.841	0.895	0.931	0.952	0.973
4	0.846	0.852	0.937	0.948	0.959	0.937
5	0.852	0.862	0.890	0.952	0.961	0.972
6	0.860	0.868	0.887	0.959	0.969	0.985
7	0.869	0.875	0.839	0.961	0.979	0.943
8	0.872	0.875	0.857	0.968	0.985	0.948
9	0.879	0.882	0.945	0.975	0.991	0.943
10	0.881	0.895	0.938	0.979	0.995	0.936

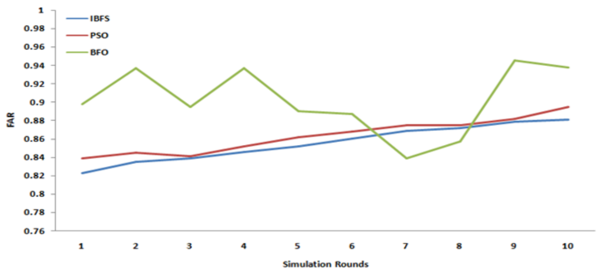

Fig.6 FAR evaluation for IBFS and other models

The evaluation of FAR (False Acceptance rate) is shown in fig.6 for the proposed IBFS and other optimization models such as PSO and BFO. In the proposed work, GA has been incorporated and other models such as, PSO and BFO (Bacterial Foraging Optimization) are used for the feature optimization. FAR is the probability of inaccurate features as certain features in the classification process. For the proposed IBFS, FAR is 0.855 approximately whereas; FAR with PSO and BFO is 0.863 and 0.903 respectively. Thus overall FAR value of the proposed model has improved by 5% and 1% with respect to BFO and PSO respectively.

A comparison is drawn with the other optimization techniques to show the effectiveness of the proposed work concerning the simulation rounds where simulation rounds are the number of simulation with different data to test the proposed model.

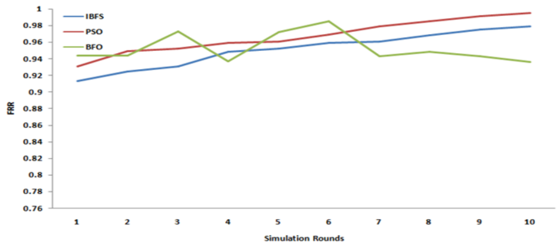

Fig.7 FRR evaluation for IBFS and other models

The comparison of FRR (False Rejection rate) for IBFS and other optimization models are depicted in fig.7. FRR is the probability of certain rejected features which are not included in the matching process. For the proposed IBFS, FRR is 0.931 approx. Moreover, FRR with PSO is 0.967 and that of BFO, it is 0.95 approximately. The overall improvement in contrary to PSO of the proposed model is $Overall\ Improvement = \frac{0.967 - 0.93}{0.967} \times 100 = 4\%$. Consequently, the improvement in contrary to BFO, it improved by $Overall\ Improvement = \frac{0.95 - 0.93}{0.95} \times 100 = 2\%$.

To show the effectiveness of the research work, accuracy plays a vital role. It can also be said that accuracy is the criterion to calculate the reliability of the system modality. In the proposed IBFS, the accuracy is 99.1% as depicted in fig.8. The average accuracy obtained by PSO and BFO is 95.4 and 91.702%. Thus, overall accuracy has been revamped by 4% and 7% approximately with respect to PSO and BFO respectively.

Table 2.Test results of proposed IBFS with the other techniques for Accuracy and Execution Time

Itr	Accuracy			Execution Time		
	IBFS	PSO	BFO	IBFS	PSO	BFO
1	97.26	94.25	92.38	0.252	0.456	0.83
2	97.79	94.25	90.82	0.291	0.487	0.95
3	97.55	95.21	89.03	0.325	0.496	1.83
4	98.62	95.34	91.39	0.375	0.512	0.76
5	99.96	95.66	93.28	0.395	0.535	0.79
6	99.22	95.74	92.11	0.426	0.598	0.83
7	98.35	95.81	90.92	0.458	0.621	0.93
8	98.56	95.92	91.99	0.472	0.655	0.73
9	99.79	96.11	93.37	0.489	0.669	0.89
10	98.21	96.23	91.73	0.502	0.678	0.82

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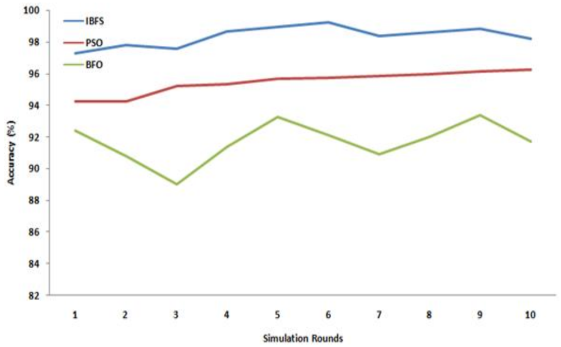

Fig.8 Accuracy evaluation for IBFS and other models

From the analysis of proposed IBFS, we have observed that the authentication accuracy is improved with the combination of biometric recognition system with image enhancement algorithm (ALA). This has to lead to enhancement in the accuracy percentage, as depicted in fig.8.

Fig.9 depicts the execution time. The execution time is the total time taken by the system to authenticate the users in the proposed IBFS. As shown in fig.9, the execution time for the proposed work is 0.398 seconds approximately and for the existing work, with PSO and BFO are 0.570 seconds and 0.936 seconds, respectively. Thus, overall execution time has been improved by 31% and 60% in contrary to PSO and BFO respectively.

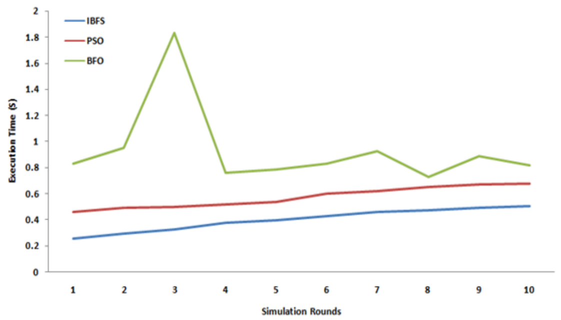

Fig.9 Execution time evaluation for IBFS and other models

It has been concluded that the proposed technique has outperformed as contrasted to the real technique because the quality of the input image is improved by using the ALA algorithm to authenticate the users. Also, the genetic algorithm is most effective optimization algorithm for feature optimization as compared to the PSO and BFO. In the genetic algorithm, feature selection ability is more because of their basic operators like crossover and mutation.

The results has been further compared with the existing work [1]to determine the efficacy of the proposed work.

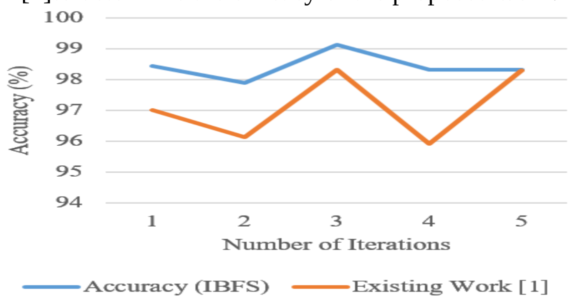

Fig.10 Accuracy Evaluation with existing work

Fig.10 depicts the accuracy of the proposed work IBFS has been compared with Rank score fusion which shows that our experimental results provides better output. The average value for accuracy of the proposed work is 99.13%. However, that of conventional approach, it is 97.1%. Thus overall accuracy has been improved by 2% in contrary to [1]. The proposed work incorporates the GA, which is a natural computing based optimization technique. So, experimental results of the proposed work with GA is better in comparison to model design with PSO and BFO. The main advantage of the proposed work with GA is that feature selection time reduces due to its natural computation as it easily adjusts in a new environment and can be trained easily. However, PSO and BFO are entirely random processes which takes more time to select the feature. Thus, performance of the proposed work is better than the other optimization models.

V. CONCLUSION

The results of analyzing our proposed IBFS have exhibited the effect of integrating IFPRS and IFRS over classification accuracy. ALA algorithm is used in the research to improve the accuracy in the pre-processing phase with the enhancement in image quality of fingerprint and face. Maximum classification accuracy is reported when IFPRS and IFRS are fused at score level. With IBFS, the accuracy is 99.1%. Thus, accuracy of the proposed work has been ameliorated by 2% and 4% with respect to PSO and BFO respectively. Consequently, FAR has been improved by 5% and 1% in contrary to BFO and PSO respectively. Similarly, other results has been improved in comparison to optimization models. The results has been further compared with the existing work to check the effectiveness which shows that results has been revamped by 2% when measuring the accuracy. Similarly, execution time has been improved by 31% and 60% with respect to PSO and BFO respectively. Meanwhile, Future lies in using Iris biometric trait with Face and Fingerprint (triple authentication) in the proposed IBFS using the concept of Artificial intelligence.

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