

# Hybrid Biometric Recognition using Stacked Auto Encoder with Random Forest Classifier

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**Abstract-** In recent years, the need for security of personal data is becoming progressively important. A biometric system is an evolving technology that is used in various fields like forensics, secured area and security system. With respect to this concern, the identification system based on the fusion of multibiometric values is the most recommended in order to significantly improve and obtain high performance accuracy. The main purpose of this research work is to design and propose a hybrid system of combining the effect of three effective models: Retinex Algorithm, Stacked Deep Auto Encoder and Random forest (RF) classifier based on multi-biometric fingerprint as well as finger-vein recognition system. According to literature several fingerprint as well as fingervein recognition system are designed that uses various techniques in order to reduce false detection rate and to enhance the performance of the system. A comparative study of different recognition technique along with their limitations is also summarized and optimum approach is proposed which may enhance the performance of the system. In order to gain above mentioned objectives, fingerprint and fingervein dataset is taken for training and testing. The result analysis shows approx. 97% accuracy, 92% precision rate as well as 0.04 EER that shows enhancement over existing work.

**Keywords-** Fingerprint, Fingervein, Image Enhancement, Retinex, Stacked Auto Encoder, Random Forest, Equal Error Rate.

## I. INTRODUCTION

Biometric recognition refers to the use of characteristic anatomical features (e.g. fingerprints, face, iris) and behavioral features (e.g. language) that are used as identifiers or biometric features or features to automatically recognize people to be designated. Biometrics is becoming an essential part of effective solutions for personal identification, as biometric identifiers cannot be transmitted or moved and reflect the individual's physical identity. The recognition of a person through his body and the subsequent connection of this body with an "identity" established from the outside constitutes a very powerful tool for identity management with enormous potential positive and negative consequences [1].

Consequently, biometrics is not only a fascinating problem in model recognition research, but if applied with care, it is a technology that can make our society safer, less fraudulent and more user-friendly [2].

Numerous biometric authentication systems have been used, but each type of unimodal biometrics has its disadvantages

depending on the characteristics, the recording device, the database and the characteristics of these characteristics [3].

Fingerprints are a popular identifier, but can be easily falsified with false fingerprints sensitive to dirt, moisture and aging [4,5].

Facial recognition depends on facial expression and age [6].

Speech recognition also depends on environmental conditions and is not safe for recorded speech [7].

Given the challenges of today's detection system, the time has come to develop a robust single-mode detection system to protect privacy. A comparative evaluation of the most important biometric methods is described in Table I. Each mode has its advantages and disadvantages.

TABLE I  
COMPARATIVE EVALUATION OF THE BIOMETRIC TECHNOLOGIES

Biometrics	Accuracy	Data Size	Cost	Security Level	Long-term Stability
Finger Vein	High	Medium	Low	High	High
Fingerprint	Medium	Small	Low	Low	Low
Face	Low	Large	High	Low	Low
Iris	High	Large	High	Medium	Medium
Voice	Low	Small	Medium	Low	Low
Hand Geometry	Low	Large	High	Low	Low

### A. Biometric System using Fingerprint

A fingerprint shows the patterns on the tip of a finger. There are several approaches for fingerprint verification. Some imitate the traditional police method of matching models. Others use minutiae that join devices; and others are a bit more unique, including things like moiré stripe patterns and ultrasound properties. A wider range of fingerprint devices is available than any other biometric technology [8,9].

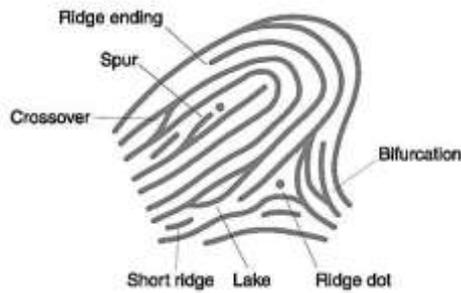


Figure 1: Features of Fingerprint

Disadvantages of fingerprint technology made scientists to think about using what is underneath the skin. Under the skin there are blood vessels which are unique to individuals (even in twins) and this uniqueness made a new biometric system based on finger veins. Biometrics based on veins, i.e., vascular biometrics are not limited to the fingers.

### B. Biometric System using Finger Vein

Finger vein detection is a method of identifying a person based on the finger vein configuration. Since deoxyhemoglobin absorbs near infrared light in the blood, venous patterns appear as a series of dark lines. The nearby infrared light in combination with a special camera captures an image of the pattern of the finger veins [10].

The image is then converted into data samples and saved as a template for a person's biometric authentication data. During authentication, the image of the finger vein is acquired and compared with the user's saved model.

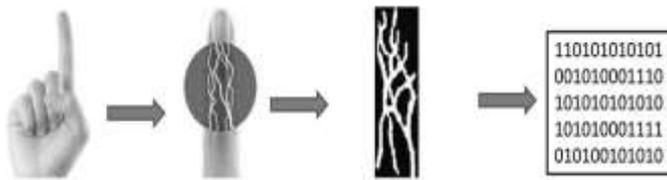


Figure 2: Features of Fingervein

## II. RELATED WORK

Das et al. [4] proposed a finger vein identification system based on a convolutional network and examined the capabilities of the network designed in four publicly accessible databases. The main objective of this article is to propose an in-depth learning method for the identification of finger veins that can obtain stable and very precise results when using images of finger veins of different quality. The in-depth experience reported shows that the accuracy obtainable with the proposed approach can exceed 95% of the correct identification rate for the four databases deemed accessible to the public.

Cihui et al. [5] introduced of a new approach to finger vein authentication by CNN and discrete hash monitoring. We also systematically examine comparative performance using several CNN architectures popular in other fields, in particular H. Light CNN, VGG-16, Siamese and CNN with coupling based on Bayesian inference. Experimental results are presented using a finger vein database in two publicly accessible sessions. The most accurate performance is

achieved by incorporating a discrete hash monitored by a CNN that was formed using the triplet-based loss function.

Wenxuan et al. [6] proposed an algorithm to effectively improve the accuracy of the position of the limit points in the localization area. By including neighborhood groups in the positioning reference, the method improves the positioning accuracy of the edge positioning points, improves the overall internal positioning effect and improves the accuracy of positioning to some extent. The simulation environment was created to verify the proposed algorithm. Experimental results show that the improved algorithm improves the positioning accuracy of the edge position points to some extent and improves the overall positioning accuracy of the edge position points.

Abiodun et al. [7] provided readers a clearer understanding of current and emerging trends in NAS models and effectively addressed public relations challenges to enable research priorities and topics. The overview also shows the different areas of success of the ANN models and their application to public relations. To evaluate the performance of the ANN model, many studies have used statistical indicators to measure the performance of the ANN model. This includes the use of the mean absolute error (MAPE), the mean absolute error (MAE), the root mean error (RMSE) and the mean absolute error variance (MAEV). The result shows that current ANN models such as GAN, SAE, DBN, RBM, RNN, RBFN, PNN, CNN, SLP, MLP, MLNN, Reservoir Computing and Transformer are suitable for public relations activities. The study therefore recommends focusing on current models while developing new models for future success in this area.

Serafim et al. [8] a method of segmentation of the region of interest based on convolutional neural networks (CNN) without pre-treatment phases. The new approach was evaluated in two different architectures of known technology and showed clear indices of Hausdorff similarity (5.92), cube coefficient (97.28%) and Jaccard similarity (96.77%), which were superior to the methods. conventional. The error rate (3.22%) in biometric identification systems.

In this research work a hybrid fingerprint and fingervein biometric system is designed and proposed. The hybrid biometric sensing system combines a variety of biometric sources [11,12]. The main advantage of the multimodal system over conventional single biometrics is that the recognition process is safer and more precise. The advantage of combining the fingerprint and finger veins is the ability to establish an image acquisition system which can capture fingerprint and finger-vein images simultaneously and its devices are less expensive and easier to deploy.

## III. PROPOSED METHODOLOGY

The important step in identifying the finger vein is to extract the vein from the background. Finger vein images are acquired using NIR spectroscopy. The venous image obtained by NIR spectroscopy appears darker than in other regions of the finger. In fact, only the blood vessels absorb the rays. The performance of the finger vein extraction and adjustment algorithm depends on the quality of the input image. First, the image is enhanced by using the filtering-oriented method to eliminate noise [13].

In this research work an approach is proposed to develop a biometric system based on the fusion of fingerprints and finger veins for biometric recognition. In order to gain above mentioned objectives, FVC2002 dataset [14] is taken for training and testing. In this dataset there are some blur, distorted as well as partial images also which are considered for recognition. Similarly, finger vein database is taken from [15] and used for experimental analysis of the proposed hybrid framework.

The algorithm is designed to match with given training dataset that gives matching result in probability.

The flowchart of the proposed methodology is discussed as below:

- Step 1: Input fingerprint and fingervein images
- Step 2: Image is enhanced using Retinex theory.
- Step 3: Separated Features are extracted from both using autoencoder with RF classifier for further processing.
- Step 4: Training the proposed network and identify the result.
- Step 5: Evaluation of Performance Parameters such as Accuracy, Precision rate and recall rate.

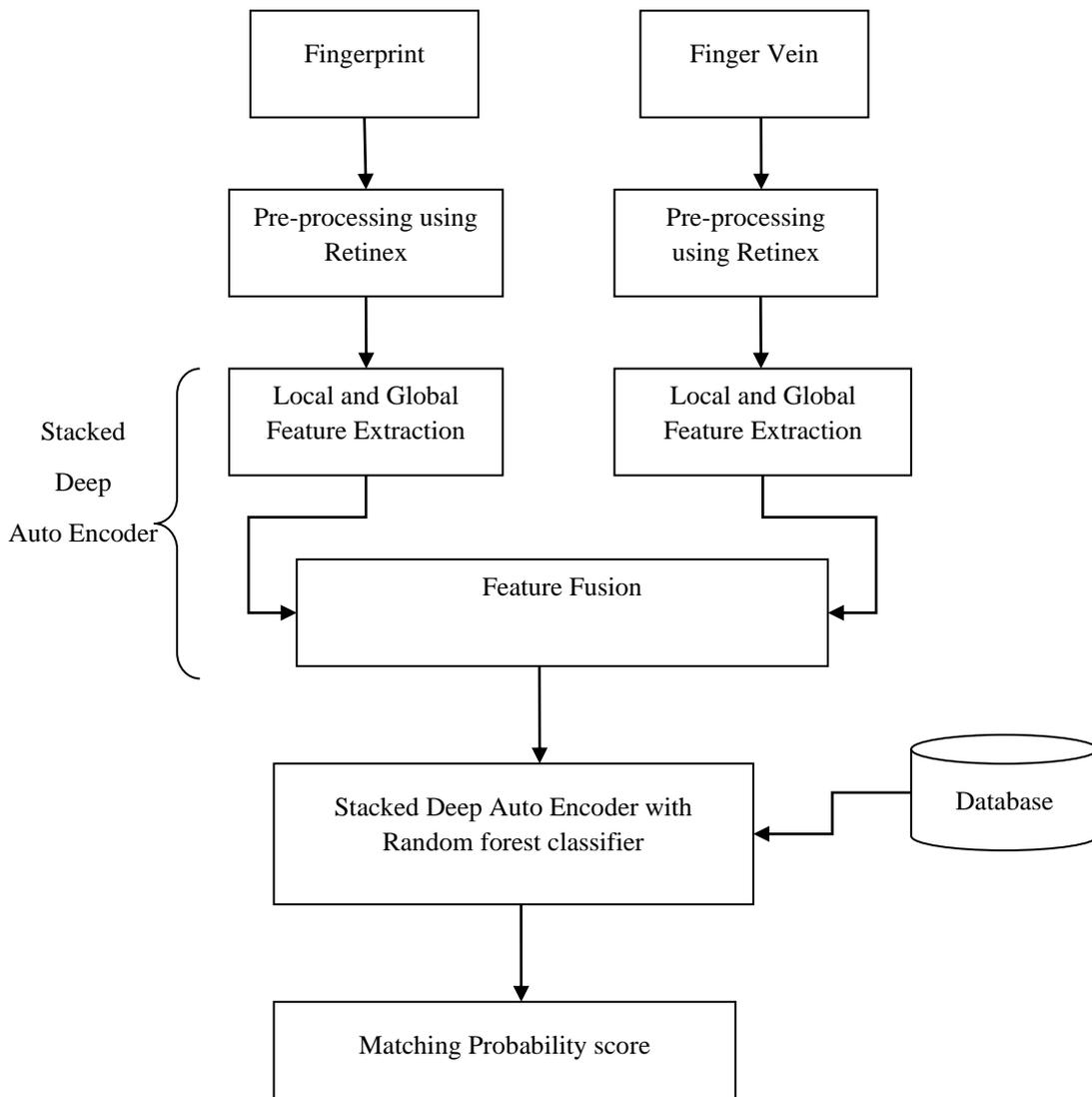


Figure 3: Proposed Hybrid Biometric Identification System

A. Data Collection

In order to design robust and efficient biometric technique, it is required to collect input images from specific condition dataset. In this research work, FVC2002 dataset is used [24]. Four different databases (DB1, DB2, DB3 and DB4) were collected by using the following sensors/technologies:

- DB1: optical sensor "TouchView II" by Identix
- DB2: optical sensor "FX2000" by Biometrika
- DB3: capacitive sensor "100 SC" by Precise Biometrics

- DB4: synthetic fingerprint generation
- Fingers from set B have been made available publicly. So, in this research work performance is evaluated using set B dataset. Similarly, finger vein database is taken from [15] and used for experimental analysis of the proposed hybrid framework. It contains fingervein of three fingers index finger, middle finger and ring finger. So, in this work 10 person samples are prepared as a dataset. In which 6 instances of finger vein are taken from index finger, middle finger and

ring finger as well as 8 samples of fingerprint are taken. Combined dataset is prepared using these two datasets for experimental analysis.

### B. Preprocessing using RETINEX Algorithm

The word "Retinex" is a combination of "Retina" and "Cortex", which indicates that the eyes and brain are involved in the process. The human visual system (HVS) is believed to be subjective when it comes to perceiving colors. The human vision system ensures that the perceived color of the lens remains relatively constant under different lighting conditions. This feature helps us identify objects. Retinex acts like the human visual system. Retinex is based on the following imaging model:

$$S(x, y) = L(x, y) * R(x, y) \quad (i)$$

where the bivariate function,  $S(x, y)$  represents an input image, every point in the domain is equivalent a pixel on the image. The image  $S(x, y)$  is composed of two images: the illumination and reflectance images, then we can separate from in order  $R(x, y)$  to  $L(x, y)$  generating Retinex effect, It seems that the problem is mathematically ill posed. There have been numerous attempts to digitally estimate the lighting image.

An image is a pixel product of pixel of ambient lighting and scene reflectivity. Since ambient lighting is independent of the object itself, only the reflectivity of the scene reflects the intrinsic properties of the object itself. Illumination is a slowly changing kind of low-frequency image information and reflectivity contains more detailed high-frequency image information. Retinex theory addresses the problem of separating the two quantities: first estimate the illumination then obtain the reflectance by division. From a mathematical point of view, based on the logarithmic interval, complex multiplication can be converted into a simple addition operation. The first step taken by most Retinex algorithms is to convert the specified image into a logarithmic range.

$$\log S = \log R + \log L \quad (ii)$$

Therefore, as shown in formula 4.3, the logarithm of the reflectance can be obtained by the logarithm of the image subtract the logarithm of the illumination

$$\log R = \log S - \log L \quad (iii)$$

Then the reflectance can be obtained by taken its index form, as shown in formula 4. The reflectance is inherent properties of object itself.

$$R = \exp(\log S - \log L) \quad (iv)$$

Since lighting is a low frequency component compared to reflectance, the Retinex algorithm uses the low pass filter to estimate illumination. However, since the Gaussian filter used in the filtering process inevitably loses some high frequency components, the image loses some detail and edges, resulting in distortion of the image.

### C. Feature Extraction using Stacked Deep Auto Encoder

Local feature representation is proposed in this section. The process consists of two steps:

1. Local patch generation
2. Local feature extraction and representation

#### 1) Local Patch Generation

Decomposing a input fingerprint and fingervein image into small patches is useful and practical and for important tissues can be picked up and unrelated ones can be get rid of. Input image,  $I$  can be composed of a group of image patches  $P_i$  as:

$$x = \{P_1, P_2, \dots, P_n\} \quad (v)$$

The location and scale of local patches are determined.

For a biometric image it is first segmented into local patches using Super pixel and a Superpixel map is obtained. Local patches essentially indicate the uniform regions.. However, the region extracted gives is an irregular shape, and it is inconvenient for local feature extraction and representation. Besides, there are some additional criterions to determine whether an image patch is qualified for local feature extraction:

- i. Let  $P_i$  be a local patch
- ii. It is removed when the area of  $P_i$  is larger than  $A_{max}$  or smaller than  $A_{min}$
- iii. Let  $P_i$  and  $P_j$  be two local patches
- iv. If the ratio between their intersection and their union is larger than  $O_t$ , then the smaller one is removed.  $A_{max}$ ,  $A_{min}$ , and  $O_t$  are predefined thresholds.

#### 2) Local and Global Feature Extraction and Representation

With the rapid development of unsupervised learning in recent years, the use of untagged data to extract functions with Autoencoder has become an appropriate medium. The Autoencoder model is essentially a multilayer neural network. A deep stacked autocoder is constructed by combining a stacked autocoder that includes a desired number of cascading automatic encoding layers. In Autoencoder networks, the learning phase of the functionalities is not monitored since no labeled data is used. The basic architecture of an unattended auto encoder is a step forward with an input level, often a hidden level and an output level.

An automatic encoder can be used for pre-training or to reduce dimensionality if the architecture has the shape of a bottleneck. For simplicity, consider a car encoder with a hidden layer. The automatic encoder can then learn different display levels by stacking the hidden levels. It is a feature extraction algorithm. Helps find a representation of the data. The functionality generated by the automatic encoders represents the data point better than the points themselves.

The main difference between ordinary forward neural network and autoencoder is that an autoencoder's output is always the same as or similar to its input. The basic formula can be expressed as follows:

$$F_v = h(x) = \sum W_e * X_i + B_i \quad (vi)$$

$$F_v' = h'(x) = \sum W_d * X'_i + B'_i \quad (vii)$$

Where

$W_e$  = weight matrices of encoder

$W_d$  = weight matrices of decoder

An automatic encoder can be considered as a combination of encoder and decoder. The encoder contains an input layer and a hidden layer which converts an input image I into a characteristic vector  $F_v$ . The decoder includes a hidden layer and an output layer that transform feature  $F_v$  to output feature  $F_v'$ . tanh activation functions, which is used to activate the unit in each layer.

And transfer function is calculated as :

$$f(x) = \frac{1}{1 + e^{-y}} \tag{viii}$$

Where, e=error value

The stacked deep autoencoder neural network involves multiple layer of autoencoders neural network and the loss function that is to be minimized as :

$$loss_{min} = |X - (W_1\theta(W_2\theta \dots \dots (W_l(f(x)))))| \tag{ix}$$

Where,  $W_1, W_2, \dots, W_l =$  weight function of all autoencoders

$\theta =$  Decoding function of autoencoders

$f(x) =$  function to calculate data values at each layer

Fundamentally, this involves the proposed shift from the encoder-decoder paradigm (symmetric) and towards utilizing just the encoder phase (non-symmetric). The reasoning behind this is that given the correct learning structure, it is possible to reduce both computational and time overheads, with minimal impact on accuracy and efficiency.

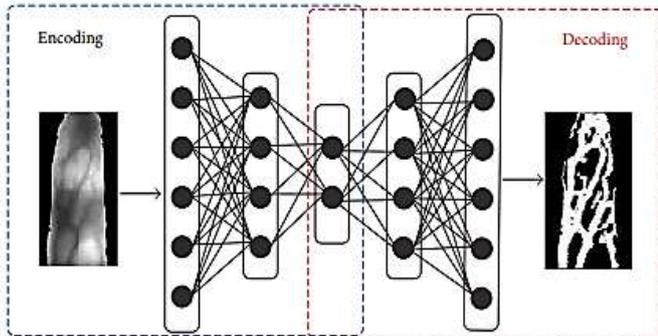


Figure 4: Stacked Deep Auto Encoder for Local Feature Extraction

Therefore, each local patch of a biometric image  $P_i$  can be represented by a fixed-length feature vector  $F_v$  with deep autoencoder model. Then it is represented as:

$$x = \{P_1, P_2, \dots, P_n\} = \{F_{v1}, F_{v2}, \dots, F_{vn}\} \tag{x}$$

And finally, all local features are combined to form the local feature of each fingerprint images as well as finger vein images. These features of fingerprint as well as fingervein images are fused together for extracting global features and these features are further used for classification of biometric identification. Random forest is used for classification of extracted biometric features for personal identification.

### 3) Random Forest Classifier

SDAE can be used as a hierarchical unsupervised feature extractor that scales well to accommodate high-dimensional inputs. It learns non-trivial features using a similar training strategy to that of a typical auto-encoder. An illustrated example of this is presented in Fig. 4.3. Hence, the deep learning power of SDAEs is combined with a shallow

learning classifier. For shallow learning classifier, Random Forest is used as classifier.

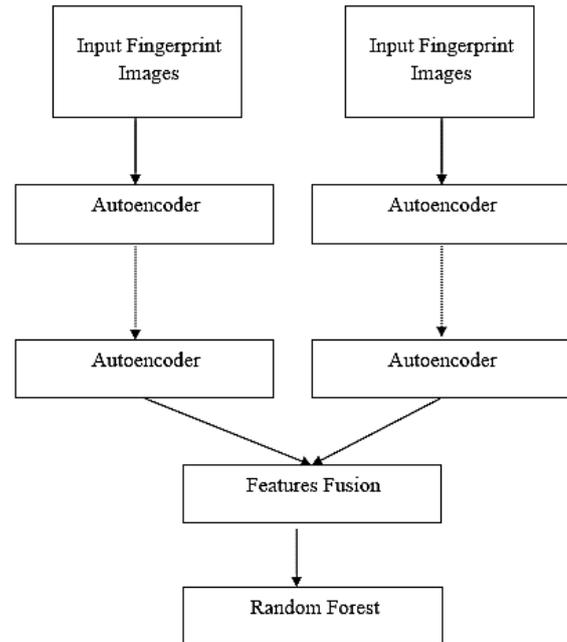


Figure 5: Stacked Deep Auto Encoder with RF Classifier

Random Forest machine learning algorithm is capable of acting each regression and classification tasks. In random forest technique many decision trees are shaped and algorithm combines the principles of those decision tree and produces an ensemble learning rules for prediction. By using ensemble of those decision trees the model produces the correct and precise results as a result of it's supposed with deep and totally different practiced learnings of many decision tree. As random forest is collection of various weak classifier and combinedly forms robust classifier which may turn out prediction and deep insight into the dataset. For training purpose the algorithm is given with random samples of dataset from that all weak decision trees learn and generates learning rules. any by combining these rules the random forest generates a powerful classifier that's combination of these weak classifiers.

The prediction is made on testing dataset. The algorithm predict the results by applying the learning rules and generates the output in form of class or label. After making different decision trees then voting is performed among them to generate strong learner. This process is termed as "bagging". In growing strong decision tree, exhaustive searches across all possible weak decision trees is conducted to find the possible path in the tree.

Before applying training data there is automatically available holdout data termed as "Out of Bag (OOB)" data. Every decision tree that are generated have different OOB because every tree has a different training sample. Keeping track of for which trees a specific record was OOB allow as to easily and effectively evaluate Random Forest performance.

## IV. RESULT ANALYSIS

To evaluate the performance of the proposed system following parameters such as Accuracy, Detection Rate, False Alarm Rate, Precision, Fmeasure and EER are used.

- Accuracy= (TP+TN)/(TP+TN+FP+FN) (vii)
- False Alarm Rate = FP/(TN+FP) (viii)
- Recall / Detection Rate = TP/ (TP+FN) (ix)
- Precision = TP/ (TP+FP) (x)
- Fmeasure = 2\* (Precision\* Recall) / (Precision + Recall) (xi)
- FAR=FP/(FP+TN)
- FRR=FN/(TP+FN) (xii)
- EER=(FAR+FRR)/2

Where,

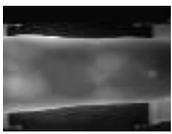
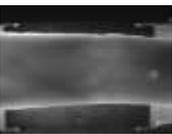
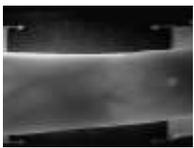
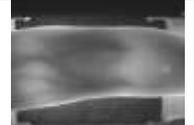
TP stands the number of true positive samples which determines that actual class of the test data is biometric feature type and classifier also predict it same.

TN stands the number of true negatives which determines that actual class of the test data is non-biometric feature type and classifier also predict it same.

FN stands the number of false negative samples which determines that actual class of the test data is biometric feature type and classifier predicts it as non-biometric feature. FP stands the number of false positive samples which determines that actual class of the test data is non-biometric feature type and classifier predicts it as biometric feature type.

The results of proposed methodology are evaluated on different input images the result analysis of some of images is illustrated in Table I.

TABLE I  
EXAMPLES OF PROPOSED METHOD OF HYBRID BIOMETRICS

Fingervein	Fingerprint	Matching Score
		1
<b>Index_101</b>	<b>Finger_101</b>	
		0.91
<b>Middle_101</b>	<b>Finger_101</b>	
		0.87
<b>Ring_101</b>	<b>Finger_101</b>	
		1
<b>Index_102</b>	<b>Finger_102</b>	

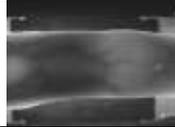
		0.96
<b>Middle_102</b>	<b>Finger_102</b>	
		0.84
<b>Ring_102</b>	<b>Finger_102</b>	

Table II represents the performance evaluation of proposed stacked auto-encoder based on random forest classifier for hybrid biometric system in terms of accuracy precision rate, recall rate, f\_measure and Equal Error Rate (EER).

TABLE II  
PERFORMANCE EVALUATION OF PROPOSED ALGORITHM

Parameters	Values
Accuracy	96.4444
Precision	92.1235
Recall	100
F_Measure	94.8052
EER	0.0494

A. Comparative Performance Evaluation

Raghavendra et al. [9] proposed a new multi-finger detection system capable of simultaneously detecting three different fingers in a single detection instance. The relevance of the images acquired for biometric applications is verified using four different verification algorithms Maximum Curvature Pattern (MCP), Spectral Minutiae Representation (SMR), Repeated Line Tracking (RLT) method and Wide Line Detector (WLD). The results are assessed and compared using individual finger vein data. The usefulness of merging scores to improve performance is also presented. Table III represents the comparative performance evaluation with respect to existing work.

TABLE III  
COMPARATIVE PERFORMANCE EVALUATION

Techniques	EER	Nature	Performance
Proposed	0.04	Hybrid	Better
MCP -CRC [9]	0.39	Fingervein	Good
RLT-CRC [9]	0.13	Fingervein	Good
SMR-CRC [9]	0.92	Fingervein	Good

WLD-CRC [9]	0.65	Fingervein	Good
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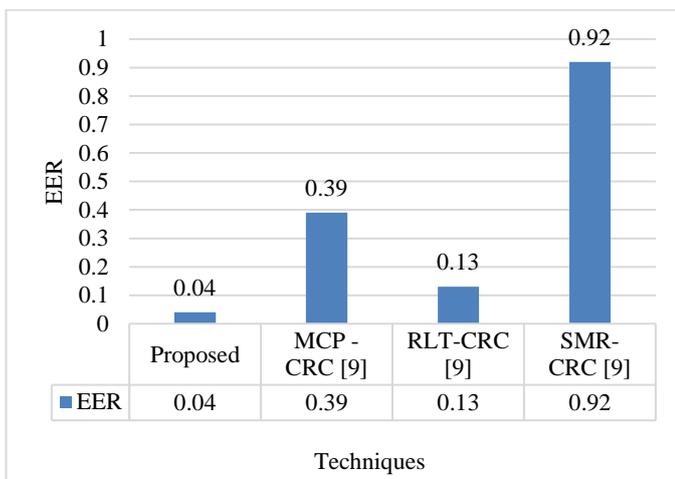


Figure 6: Comparative Performance Evaluation

Figure 6 represents the comparative performance evaluation of proposed hybrid biometric identification system with respect to existing work for fingerprint recognition.

## V. CONCLUSION

Biometrics is a technology which identifies a person based on his physiology or behavioral characteristics. The main purpose of this research work is to develop a hybrid fingerprint and fingervein biometric system. In this work, a recognition system that uses Retinex, SDAE and RF models and a multimodal biometric identification system based on the fusion of fingerprints and fingervein were introduced. The result analysis is performed using parameters i.e. Accuracy, Precision, Recall, F\_measure and EER. The comparative evaluation of EER is performed and proposed algorithm gains EER equals to 0.04 whereas existing work gains EER equals to 0.16. This shows that identification rate of proposed algorithm is high as compared to existing algorithms. Finally, it is concluded from result analysis that the proposed multimodal system is superior to existing method because:

1. The proposed enhanced fingerprint and finger vein patterns are significantly clearly distinguishable due to Retinex Algorithm. Therefore, the proposed methods are typically able to guarantee a high identification rate.
2. SDAE approach can usually provide better performances than using combinations between different processes such as windowing, extracting features, etc.

The proposed multimodal algorithm have higher accuracy to identify the person and ensure that its information or data is safer compared to system based on single or bimodal biometrics.

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