

# Analysis of Score Level Fusion of Biometric Features

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**ABSTRACT-** Biometric systems have gained acceptance in a variety of industries in recent years, and they continue to improve security features for access control systems. Numerous types of monotonic biometric systems have been developed. On the other hand, these systems can only provide low- to mid-level security features. As a result, combining two or more collinear biometrics are necessitated for significantly greater functionality. In this paper, a multimodal biometric technology for iris, face, and fingerprint assimilation has offered. Here, an effective matching approach based on Principal Component Analysis that employs three biometric modes to solve this challenge: iris, face, and fingerprint. The three modalities are integrated at the score level fusion, and fusion is conducted. Here, authors have proposed a combination of Iris-Fingerprint, Iris-Face, and Face-Fingerprint to develop the model. Statistical parameters like True positive (TP), True Negative, False positive, False Negative, F1 score, Accuracy are tested for different threshold values. For Iris-Fingerprint, Iris-Face, and Face-Fingerprint, our suggested technique yields accuracy of 79 percent, 85 percent, and 82 percent, respectively. Finally, a ROC curve was created using a Linear Support Vector Machine for all of the combinations, with an Area under Curve of 0.83 for the fusion of Iris and Face.

**Keywords:** Area under Curve, Biometric systems, Multimodal, Principal Component Analysis, Score level fusion, Support Vector Machine.

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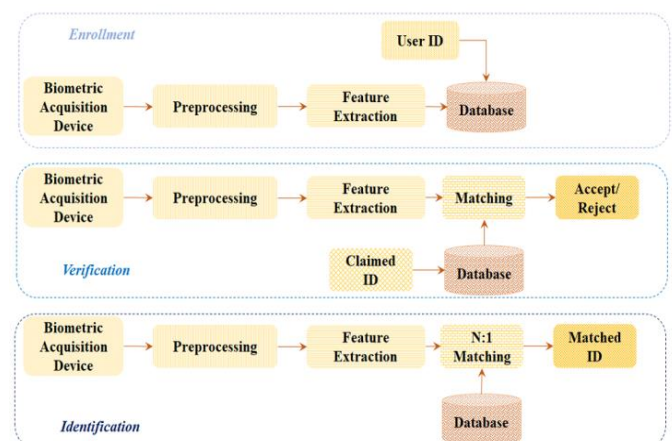
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## 1. INTRODUCTION

Over the last decade, the high and rising demands on robotic systems have prompted developers and biometric system designers to strategize and consider ways to improve recognition accuracy and system performance. As a result, for many developers, the strength of the biometric system has become the most important and critical factor [1]. The word biometric implies a method of authentication or recognition that uses the basic features of the behavior or physiology. The biological features of human beings such as fingerprint, iris, speech, face, and hand etc. are used in biometrics. Since their reliability has been established, biometric identification technologies have been widely deployed. Biometric can be a Unimodal or Multimodal system. Unimodal system is one-way biometric system, or a pure means of authentication or identity information. Although biometric approaches appear to be extremely strong, single biometric systems relying on a single biometrics signature or resource are now incapable of guaranteeing a high recognition rate. In Furthermore, the following issues frequently plague these systems [2-3]; Sensor noise, quasi, lack of distinctiveness, lack of form that contains,

and sensitivity to attacks are all factors to consider.

Recently, several academics have investigated the possibility of combining two or more biometrics to get better identification performance along with authentic security. [4-6]. Due to its simplicity and low acquisition cost, multimodal biometric recognition, which relies primarily on the combination of several traits collected by sensors has grown in popularity. The following two types of systems are classified as such: (1) Fingerprint - palm print systems, for example: are based on single-spectrum pictures. [7-10], gait - body structure, palm vein - hand geometry, palm vein - hand geometry, finger vein - finger shape; and (2) Systems that rely on multispectral pictures [11-12]. *Figure 1* give you an idea about the three working stage of biometric system.



**Figure 1:** 3-working stages of biometric system

Fusion on the corresponding scoring level is considered as score-level fusion. As a result, it's also referred as matching-level fusion. At this level, multiple matching scores acquired from dissimilar classifiers or biometrics can be combined for identical. There are 2 approaches to fusion at the matching level [13]: as a classification problem and as an issue of combining information. Matching scores generated based on individual matches in the classification procedure are used to assemble a feature vector. After that, the trait vectors are categorized as "Accept" (actual user) or "Reject" (fake user) (impostor). Individually identical scores are merged to give a single scalar score, which is used in the information combination strategy to make the final choice. Before fusion, individual matching scores must be normalized to an identical field.

In the literature, novel approaches to rating level fusion have been investigated. One of the most well-known way is the sum rule, in which distinct modal scores are put together and a final score is obtained. Even though, it is the trouble-free way, it does not ensure that all points on the ROC are perfect. Signal detection theory produces ROC curves. It is proved that there is a trade-off between true positive and false positive rates. True positive rate refers to the ratio of correctly identified positive tuples, while false positive rate refers to the relative amount of incorrectly identified negative tuples.

Match scores are normalized to a common area before being merged in transformation score fusion. For normalization, support vector machines (SVM), probabilistic neural network classifiers, and other classifiers are utilized.

Scores from several matchers are considered feature vectors in the classification based score fusion technique, and then a classifier is built to detect authentic and imposter scores. [14]. SVM is a model or technique that can be used to classify both linear and nonlinear data. The original data is transformed into higher dimensions using a mapping approach. It finds the linear optimal separation hyper-plane in this additional dimension. SVM uses support vectors to find this hyper-plane or training tuples. SVM preserve be used for both diagnosis and detection [15]. SVM classifier was used to classify biometric and voice synthesis codes. They compared the performance of multifunctional identification technologies to several multi biometric systems based on fingerprint and voice biometric features at the measurement level. Based on their findings, they found that fusion-based biometric systems have a greater recognition performance. The results of their experiment are shown in the table below.

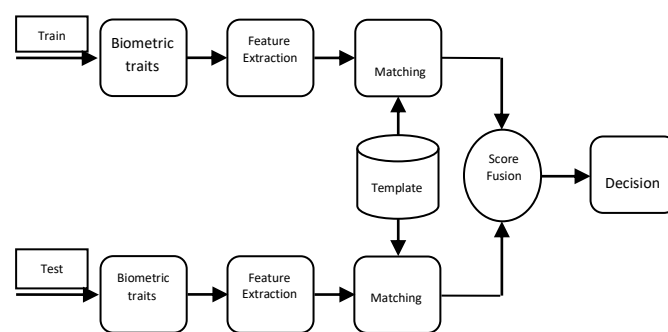
The technique for achieving the expected performance is score level fusion with particle swarm optimization. They created a new architecture for combining several features in an adaptive manner to achieve the optimum performance for a strong security. Using the sigmoid function, Yali Zang et al. [16] anticipated a score level fusion strategy with prior facts of fingerprints and presented a new category of information.

Biometric techniques are typically designed to provide binary decisions that accept authorized individuals while rejecting

impostors or unauthorized entities. As stated in the preceding literature review, unimodal biometric models have several restrictions that are overcome by using a multimodal biometric system. Hence there is a need of a multimodal system using the most frequently used biometric traits, like, face, fingerprint, and Iris. In the proposed method combination of these major traits like Iris-Fingerprint, Iris-Face and Face-Fingerprint have been used. To extract essential features from all of the attributes, the proposed criterion employs the Principal Component Analysis (PCA) algorithm. Finally, using Linear Support Vector Machine proposed model is tested using the different statistical parameters like True positive (TP), True Negative, False positive, False Negative, F1 score, Accuracy and Area Under Curve for all the combinational biometric traits.

## 2. MATERIALS AND METHODS

The majority of biometric frameworks used in real-time applications are unimodal biometric frameworks, which collect data from a single feature. Because there are some limits with the modalities we chose, single features may not correctly detect person. These constraints are overcome by combining different biometric modalities and performing a fusion process [17]. The proposed work of score level fusion based biometric multimodal system for different modalities is as illustrated in *Figure 2*. The projected system consists of three individual subsystems for the biometric traits used for the recognition system. In the proposed work individual systems has been developed for Iris, Face, and fingerprint image. Prior to the fusion, features corresponding to the Face, Fingerprint, and Iris are extracted as per the individual. For each window, these features concatenated to produce a single model.

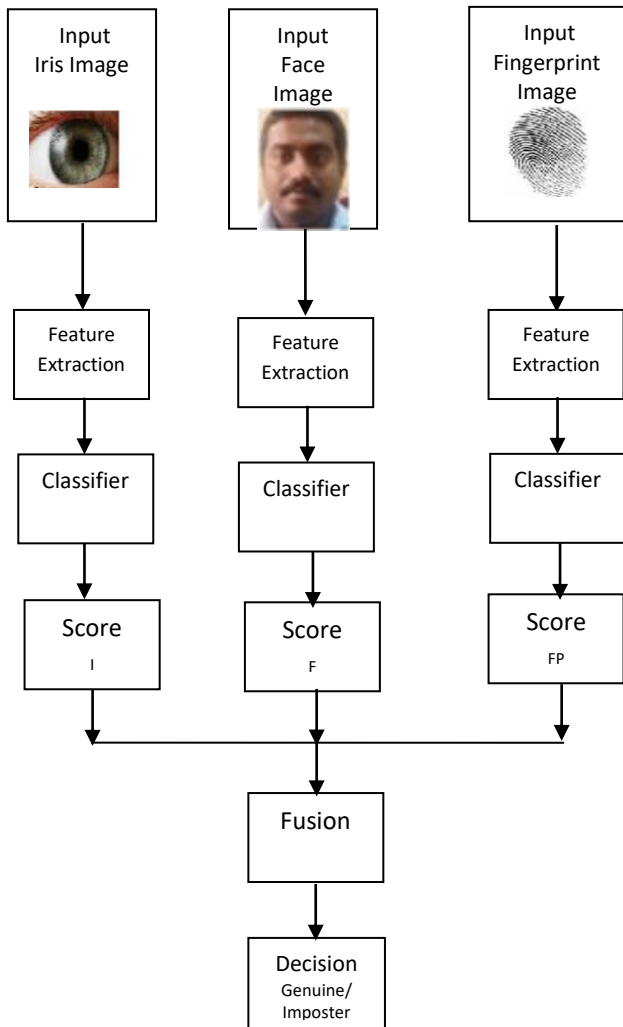


**Figure 2:** Score Level Fusion based biometric multimodal system

A new mix of iris, face, and fingerprint biometrics is proposed in this research. These features were combined for each window to create a single classifier model. For the creation of a biometric system, architecture for training and testing the model has been built. The proposed architecture to train the model is as shown in *figure 3*.

Iris, fingerprint, and face biometric features are sent via PCA and SVC independently. In the proposed decision fusion technique, OR gate has been implemented. During fusion process combination of traits like Iris-Fingerprint, Iris-Face and Face-Fingerprint has been used. Binary outputs like *Score I*, *Score F*, a

nd Score  $FP$  from the individual traits from the respective classifier will be utilized for the decision purpose. The final Score  $S=S_1+S_2$  is compared with the threshold value to decide genuinely of the person.



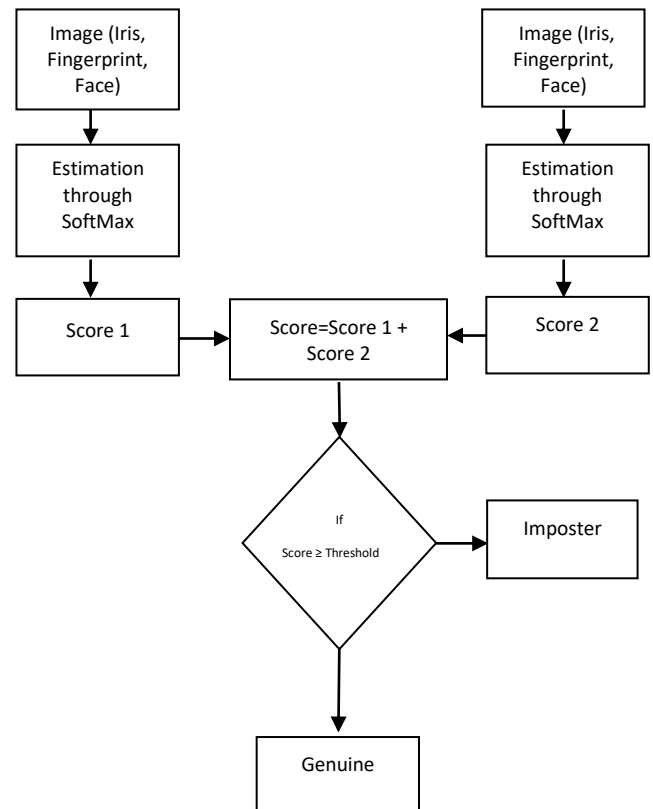
**Figure 3:** Flow diagram of the Proposed Method for Train the Model

**2.1 SoftMax**

SoftMax function as given in Equation (1) has been applied to generate score for each of the biometric feature.

$$\sigma(z)_i = \frac{e^{z_i}}{\sum_{j=1}^K e^{z_j}} \text{ for } i = 1, \dots, K \text{ } z = (z_1, \dots, z_K) \in \mathbb{R}^K$$

Where  $z$  is the input parameter, and  $e^{z_i}$  is the typical input vector for the training dataset,  $K$  counts the set of classes and  $e^{z_j}$  for the output vector; the conventional exponential function is used. SoftMax will normalize the scores obtained for individual of the biometric features. Finally, the scores obtained for each of the biometric feature has been summed as shown in figure 4. Finally, if the classifiers recognize the person with the appropriate threshold value, the decision is yes; otherwise, the decision is no.



**Figure 4:** Fusion at score level and Decision

**2.2 Principal component analysis (PCA)**

PCA among the most significant aspects of linear algebra and it is widely being adopted for analysis purpose [18-20]. Since it is simple and non-metric method it can be used in neuroscience as well as in computer graphics. PCA guide show to reduce a high dimension data to a lower dimensional data to explore only the sufficient and important features [21]. The important aspect of PCA is to minimize a data set's dimensionality consisting of removing a vast number of associated variables and retaining only the most significant data aspects. This is achieved by modify the data to an intent of inconstant called the principal components (PCs). Removing a vast number of associated variables and retaining only the most significant data aspects [22-26].

**2.3 Support vector machine (SVM)**

A SVM [19] which is used to classify data which are linearly separable is called linear SVM which is depicted in figure 5. Steps involved in finding the Maximum Margin Hyper-plane are discussed below:

1. Consider a problem of binary classification consisting of  $n$  training data.
2. Each tuple is represented by  $(X_i, Y_i)$  where  $X_i = (x_{i_1}, x_{i_2}, \dots, x_{i_m})$  corresponds to the attribute set for the  $i^{\text{th}}$  tuple (data in  $m$ -dimensional space) and  $Y_i \in \{+, -\}$  denotes its class label.
3. Given  $\{(X_i, Y_i)\}$ , a hyper-plane is generated which separates all  $X_i$  into two sides of it.

- Take a two-dimensional training data set with attributes  $A_1$  and  $A_2$  as  $X = (x_1, x_2)$ , where  $x_1$  and  $x_2$  are the values of  $A_1$  and  $A_2$  for  $X$ , respectively.
- Equation of a plane in 2-D space can be written as  $w_0 + w_1x_1 + w_2x_2 = 0$  [e.g.,  $ax + by + c = 0$ ]  
Where  $w_0, w_1$  and  $w_2$  are some constants defining the slope and intercept of the line.

Any point lying above such a hyper-plane satisfies  $w_0 + w_1x_1 + w_2x_2 > 0$

Similarly, any point lying below the hyper-plane satisfies  $w_0 + w_1x_1 + w_2x_2 < 0$

- An SVM hyper-plane is an n-dimensional generalization of a straight line in two dimensions.
- Euclidean equation of a hyper-plane in  $R_m$  is  $w_1x_1 + w_2x_2 + \dots + w_mx_m = b$  (3)  
Where  $w_i$ 's are the real numbers and  $b$  is a real constant.
- In matrix form, a hyper-plane thus can be expressed as  $W.X + b = 0$  (4) where  $W = [w_1, w_2, \dots, w_m]$  and  $X = [x_1, x_2, \dots, x_m]$  and  $b$  is a real constant.

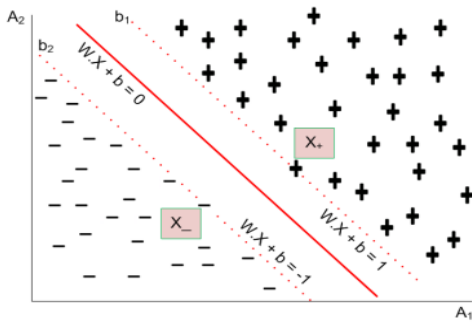


Figure 5: Shows the computation of MMH

### 3. RESULTS AND DISCUSSION

In order to discuss and present the results of this investigation a data-base collecting 500 biometric images like Iris, Fingerprint and Face with different pixel size have been used. Out of 500 images for each trait, 400 images used for training purpose and remaining 100 images are used for the test purpose. Further, standard data base like UBIRIS for Iris images, FVC for fingerprint data base and Yale data base for face has been considered. At the time of feature extraction image of each traits will be resized to  $37 * 50$ . The True Positive Rate (TPR), False Positive Rate (FPR) and Accuracy have been presented for each combination and accuracy has been evaluated over different probability threshold values. The statistical measures of results obtained through different score level fusion models have been presented in Table 2-4.

The maximum accuracy was achieved at Threshold  $\geq 1.5$  in all the models. The accuracy of the models is presented in figure 6.

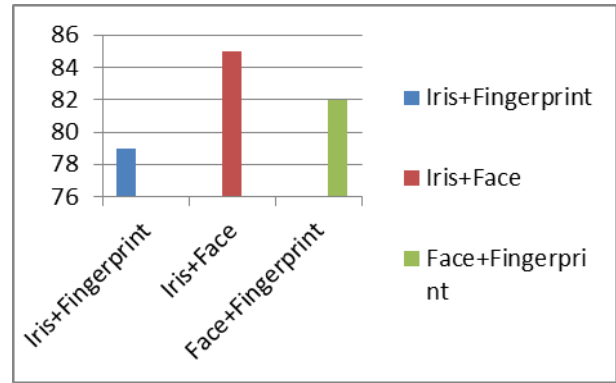


Figure 6: Accuracy of different models

From the result presented in figure 6, accuracy of 79%, 85%, and 82% is obtained for the combination of biometric traits Iris-Fingerprint, Iris-Face and Face-Fingerprint respectively. It is found that the more accuracy can be achieved through fusion of Iris and Face.

AUC For IRIS+FINGER PRINT 0.7919999999999999  
AUC For IRIS+FACE 0.8331999999999999  
AUC For FACE+FINGER PRINT 0.7968

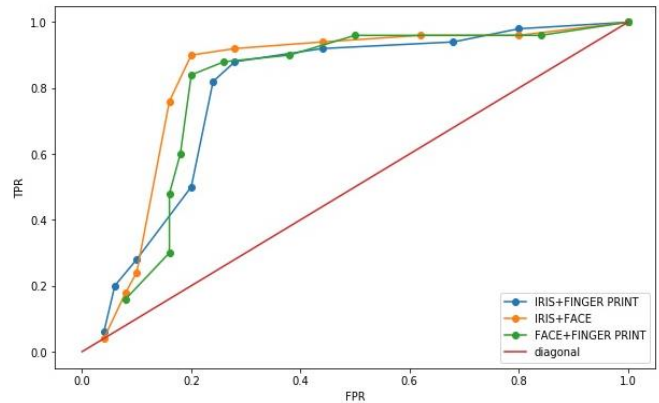


Figure 7: ROC for different models

The proposed designs are in step one and step two in figure 1a. The first design achieved the dual-band characteristic with a resonating frequency of 26.89 and 37.41. However, the gain was low, which was improved in step 2 in figure 1b to 6.8 and 7.4 at the respective bands of operation. As shown in figure 1c, the third step enhanced the Bandwidth to 1.5GHz and 4.3GHz at the individual bands.

Figure 7 explains the ROC for different models. Receiver Operating Characteristic (ROC) Curve has been drawn and Area under Curve (AUC) has been evaluated for three different fusion models. The AUC obtained is 0.7919, 0.8331, and 0.7968 for Iris-Fingerprint, Iris-Face and Face-Fingerprint respectively. The AUC achieved from the fusion of Iris - Face is higher compared to remaining models. It shows that Iris-Face is a good fusion model for classification



**Table 1: Multimodal accuracies for face-iris (Yale –UBIRIS) datasets.**

Sl. No	Method	Accuracy
1	LBP	84.53
2	GLCM	81.09
3	FDs	80.62
4	Proposed method: PCA & SVM	85

As a result of the findings in *Table 1*, we can conclude that our proposed method, when compared to other methods, provides better accuracy.

**Table 2: Iris and Fingerprint**

Threshold	TP	TN	FP	FN	TPR	FPR	Precision	Recall	F1 Score	Accuracy
$\geq 0.0$	50	0	50	0	1	1	0.5	1	0.6667	50%
$\geq 0.3$	49	10	40	1	0.98	0.8	0.5505	0.98	0.7050	59%
$\geq 0.6$	47	16	34	3	0.94	0.68	0.5802	0.94	0.7175	63%
$\geq 0.9$	46	28	22	4	0.92	0.44	0.6764	0.92	0.7796	74%
$\geq 1.2$	44	36	14	6	0.88	0.28	0.7586	0.88	0.8148	80%
$\geq 1.5$	<b>41</b>	<b>38</b>	<b>12</b>	<b>9</b>	<b>0.82</b>	<b>0.24</b>	<b>0.7735</b>	<b>0.82</b>	<b>0.7961</b>	<b>79%</b>
$\geq 1.8$	25	40	10	25	0.5	0.2	0.7142	0.5	0.5882	65%
$\geq 2.1$	14	45	5	36	0.28	0.1	0.7368	0.28	0.4057	59%
$\geq 2.4$	10	47	3	40	0.2	0.06	0.7692	0.2	0.3174	57%
$\geq 2.7$	3	48	2	47	0.06	0.04	0.6	0.06	0.1090	51%

**Table 3: Iris and Face**

Threshold	TP	TN	FP	FN	TPR	FPR	Precision	Recall	F1 Score	Accuracy
$\geq 0.0$	50	0	50	0	1.00	1.00	0.5000	1	0.6667	50%
$\geq 0.3$	48	10	40	2	0.96	0.80	0.5455	0.96	0.6956	58%
$\geq 0.6$	45	19	31	2	0.96	0.62	0.6076	0.96	0.7442	67%
$\geq 0.9$	45	28	22	3	0.94	0.44	0.6812	0.94	0.7899	75%
$\geq 1.2$	46	36	14	4	0.92	0.28	0.7667	0.92	0.8363	82%
$\geq 1.5$	<b>45</b>	<b>40</b>	<b>10</b>	<b>5</b>	<b>0.90</b>	<b>0.20</b>	<b>0.8182</b>	<b>0.90</b>	<b>0.8571</b>	<b>85%</b>
$\geq 1.8$	38	42	8	12	0.76	0.16	0.8260	0.76	0.7916	80%
$\geq 2.1$	12	45	5	38	0.24	0.10	0.7058	0.24	0.3582	57%
$\geq 2.4$	9	46	4	41	0.18	0.08	0.6923	0.18	0.2857	55%
$\geq 2.7$	2	48	2	42	0.05	0.04	0.5000	0.04	0.0833	53%

**Table 4: Face and Fingerprint**

Threshold	TP	TN	FP	FN	TPR	FPR	Precision	Recall	F1 Score	Accuracy
$\geq 0.0$	50	0	50	0	1	1	0.5	1	0.6667	50%
$\geq 0.3$	48	8	42	2	0.96	0.84	0.5333	0.96	0.6857	56%
$\geq 0.6$	48	25	25	2	0.96	0.5	0.6575	0.96	0.7804	73%
$\geq 0.9$	45	31	19	5	0.9	0.38	0.7031	0.9	0.7894	76%
$\geq 1.2$	44	37	13	6	0.88	0.26	0.7719	0.88	0.8224	81%
$\geq 1.5$	<b>42</b>	<b>40</b>	<b>10</b>	<b>8</b>	<b>0.84</b>	<b>0.2</b>	<b>0.8076</b>	<b>0.84</b>	<b>0.8235</b>	<b>82%</b>
$\geq 1.8$	30	41	9	20	0.6	0.18	0.7692	0.6	0.6741	71%
$\geq 2.1$	24	42	8	26	0.48	0.16	0.75	0.48	0.5853	66%
$\geq 2.4$	15	42	8	35	0.3	0.16	0.6521	0.3	0.4109	57%
$\geq 2.7$	8	46	4	42	0.16	0.08	0.6667	0.16	0.2580	54%

## 4. CONCLUSION

The present research work has conducted experiment using three different biometric features such as Iris, Fingerprint and Face. Two efficient algorithms namely PCA and SVC have been adopted for features extraction and classification respectively. Score level fusion has been used to fuse the result of biometric features. From the result, it is found that the score level fusion with Iris-Face providing better accuracy of 85% compared to score level fusion with Iris-Fingerprint and Face-Fingerprint. From the ROC curve obtained, it is found that AUC achieved for fusion of Iris and Face is 0.83 and it indicates that the fusion is a good classification model.

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