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Implementation Of A Multimodal Biometrics System Based On A Feasible Fusion Of Single-Matching Methods

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ABSTRACT - A biometric system in which evidence of identity is based only on a certain biometric trait. Multimodal biometric recognition is a new trend that is growing rapidly. Typical multimodal biometric authentication solutions use more memory, have poor response rates, and have greater adoption and operating costs. This article presents an innovative structure for multimodal biometric identification systems that is adaptable to any form of biometric, resulting in a reduced memory footprint and speedier implementation. The suggested framework is validated by the building of a fusion system based on a single main component matcher for faces, fingerprints, and palm prints. The system is extensively tested using fusion in identification mode. The results indicate that the system outperforms a single unimodal system in terms of precision and is also equivalent to a standard multimodal system to achieve an outcome.

Keywords: Unimodal/Multimodal Biometrics, feasibility, fusion, low cost, tiny memory, single matcher.

1. Introduction

Unimodal biometrics suffer from various flaws that lessen the system's recognition efficacy. These flaws include noise produced at the sensor level when recording the trait, non-possession of the trait by some samples enrolled in the system, and susceptibility to counterfeit assaults. The drawbacks of Unimodal biometrics are addressed by Multimodal biometrics, which vastly enhances the recognition accuracy of the system while simultaneously enhancing its resistance to fraud. Using primarily feature/match score/decision fusion techniques, multimodal biometrics integrates biometric inputs from multiple sources [9-11].

A recent innovation in the realm of data security is multimodal authentication systems. Multi-modal Biometrics is able to identify a person by using a wide variety of biometric characteristics. Due to the existence of multiple independent biometric parameters, multi-modal biometrics are more trustworthy than single-modal biometrics. Using a combination of different biometric identifiers, these methods are very secure [14] when it comes to confirming someone's identity. Due to the extensive study of multimodal biometrics by the scientific community and the development of technology, its implementation in practical settings is now essential. Noise, reduced universality, intra-class variances, and spoof attacks are just some of the challenges faced by single-modality biometric systems. Alternatively, multimodal biometric systems are becoming increasingly popular as a result of their superior accuracy, reliability, and security [9].

Typically, the foundation of a biometrics system is some aspect of an individual's biology or behaviour. The face is one of the personal characteristics that each person keeps secret from others. We are able to place those by their faces alone. A person's fingerprint, iris, and footprint are all examples of physiological traits. The tone of one's voice, the shape of one's handwriting, the speed with which one types, and even one's walks are all examples of behavioral traits. There are now a number of other features, however, not all of them may be classified as biometrics features. Only truly distinctive features can be chosen as biometric ones. Numerous physiological and behavioural factors are used in the system, and their reliability, the veracity of an individual's identification, and the system's special functionality are all dependent on these factors. A system's precise and observable output is directly proportional to the number of physical and behavioural characteristics it employs. The system's output is improved in accuracy and quality as more physical and behavioural characteristics are used. However, the system's speed and storage capacity will be affected by the incorporation of a large number of physical and behavioural

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characteristics. Our efforts have also reduced the system's memory footprint and increased its performance. Consequently, performance and accuracy are enhanced while memory usage is reduced.

The importance of security has led to a renewed interest in using a mix of biometrics. A fusion technique [15] for personal identification based on fingerprints and iris biometrics was put to the test in this research effort. The use of multiple biometrics, rather than just one, can result in considerable gains in performance that would otherwise be impossible to achieve. Combining fingerprints and irises [12] is a cost-effective alternative to purchasing the most advanced commercial systems. Using a massive fingerprint database, researchers were able to demonstrate that combining fingerprints significantly improved performance. Surprisingly, the top-performing algorithms had very little in common with one another, suggesting that there is considerable room for improvement in this area.

With an increased focus on security, the combination of several biometrics has recently attracted more attention. A fusion technique for personal identification based on fingerprints and iris biometrics was put to the test in this research effort. Using a combination of two or more biometrics can provide a significant performance boost that may not be attainable with a single biometric indication alone. A fusion of fingerprint and iris can be simply applied to various applications without the need to acquire the best commercial solutions, making it a cost-effective option. Experiments using a huge database of fingerprints reveal that combining them yields a significant boost in performance. There was surprisingly little association between the best-performing algorithms, indicating that there is still a lot of space for development in this area [13][14].

2. Related Work

Numerous researchers in this subject have published their work on various dimensions in which the accuracy of multimodal biometrics was determined at various levels, including the following: In this chapter, Melin and Castillo (2005, p. 14) described a clever method for combining results from biometric recognition techniques like face recognition, fingerprint recognition, and voice recognition. To implement the suggested method, a fuzzy system will be used to implement the decision unit of the human recognition hierarchy. In order to determine how much of the "multimodal improvement" is due to combining findings from different sensing modes rather than just a large number of images, Chang et al. (2005) [8] used this criterion to evaluate a 2D+3D recognition system. PCA-based algorithms are used for each modality separately for multimodal recognition, and the match scores in the various face spaces are pooled.

Deshpande (2015) [9] offers a system that combines fingerprints, palm prints, and faces at the score level during authentication. During enrolment, three biometric traits are collected. During authentication, query images are compared to stored templates, yielding a match score. It is proposed to use AOV to match fingerprints, PCA to compare images of faces, and PCA to generate a matching score for palm prints.

In a novel presentation of combined biometrics, Benaliouche and Touahria (2014) [7] emphasized the importance of iris traits in the fusion of fingerprints and opted for a wider range of recognition scores. The weight was simply an appreciation we assigned to the matching distance for each biometric set using a fuzzy membership function.

User identification accuracy was calculated for each tested attribute and when they were combined; for both, it was 81%; for the proposed fingerprint algorithm, it was 62.5%. This was evidence that the combination of facial and fingerprint characteristics was taken into account concurrently in a multimodal system, as demonstrated by Szymkowski and Saeed (2017) [22].

Using a PCA-based neural network classifier for feature extraction from face and ear images and hamming distance to calculate iris templates, Barde et al. (2014) [6] improved performance by combining these modalities for identification. Eigenfaces, Eigen ears, and an iris template were used for identification, and their features were verified against a self-created image database.

Barde (2017) [3] used four traits, including facial features, ear features, iris features, and foot features, to test their work on a self-built database of 100 people. They used principal component analysis for the faces, eigen images for the ears, the hamming distance-based technique for the irises, and modified sequential Haar transform for the feet.

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This work implements two feature-level fusion techniques for fingerprint and online signing, the early fusion strategy incorporating fingerprints and online signatures before fully connected layers and the late fusion scheme incorporating fingerprints and online signatures after fully connected layers. Both strategies are tested on a new multimodal collection consisting of 1400 fingerprints and 1400 online signatures.

Using the PCA classifier's matching score for the face and palm modalities, Singh and Barde (2022) [20] presented an identification method that combines facial and palmprint modalities. They used the Gaussian filter for feature extraction and the Harris method for corner detection. They then computed their outcome at two fusion levels: the matching score and the decision level.

For their own Face and Fingerprint Region database, Barde and Singh (2022) [5] used LBP (Local Binary Pattern) with PCA for face extraction and minutiae extraction for figure print. They also developed an adaptive trait-matching system to aid in classification, which condenses high-dimensional dense qualities into a significantly more compact representation. Finally, they used fusion to encode features for the Multi-SVM classifier.

3. Proposed Multimodal Biometric system

One of the primary goals for developing the proposed architecture is to demonstrate that a successful operational multimodal biometric authentication may be created not requiring the usage of two completely unimodal systems. Although the standard multimodal technique is beneficial, it does have some drawbacks. In a system, each trait has its own feature extraction set and matching approach that calculates the match score after that normal It required an additional normalization method to make similar the data and a complex fusion method that increased the process and memory shown in figure 1.

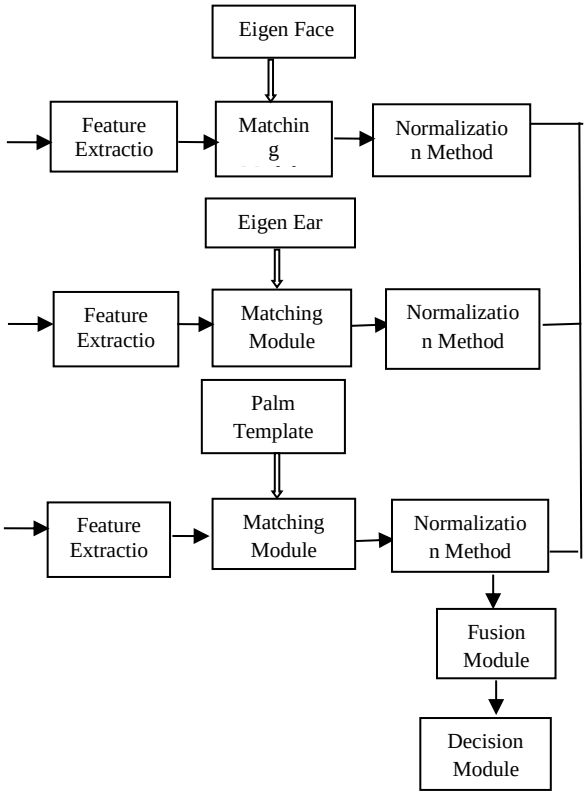

Fig.1 Conventional Multimodal Biometrics System

Our proposed framework reduced the complexity of the conventional multimodal biometrics system by removing the different matching approaches and normalization methods. This system applies the sequential flow of work. The input image is captured, and after pre-processing and segmentation it is passed to features extraction

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and compared with the database stored in the template by applying a matching classifier in between the second input is acquired and process the next steps. At this time the first process is completed and generates the match performance as an output and the second process is ready to generate the output same matcher is used to compare with the dataset and generate the match score output same work is performed on the third input. Then fusion is applied to take a decision person's modalities are matched or not [15].

The advantages of the proposed framework are that it used the same matcher classification for the three modalities to calculate the performance that removes the normalization process. While this improves performance and memory use, it also simplifies the design process, making it more efficient.

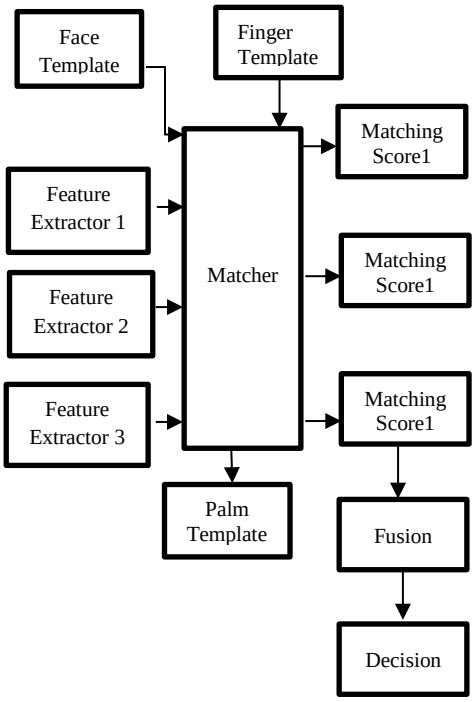

Fig.2 The proposed framework of the multimodal biometrics system.

4. Experimental System

Our proposed framework demonstrates a useful way and its result is more effective than the conventional system. This system used the standard dataset of 3 unique images of each modality of a100 people. to perform the test 100 images are used on the standard training dataset of 300 images. The following steps are used in the testing of a system shown in Figure 3.

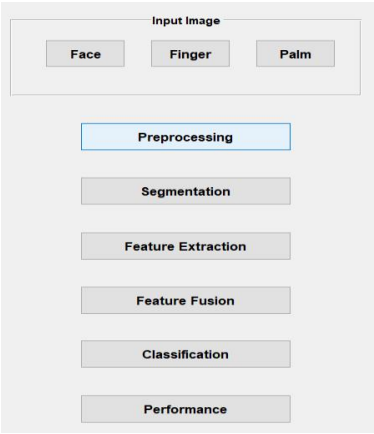

Fig.3 The Testing process of the multimodal biometrics system

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4.1 Data Collection

The proposed system worked on the pre-prepared standard dataset of face, finger, and palm print for the finding the result of imposter and genuine figure 4 shows the data sample of face images, fingerprint, and palm print images.

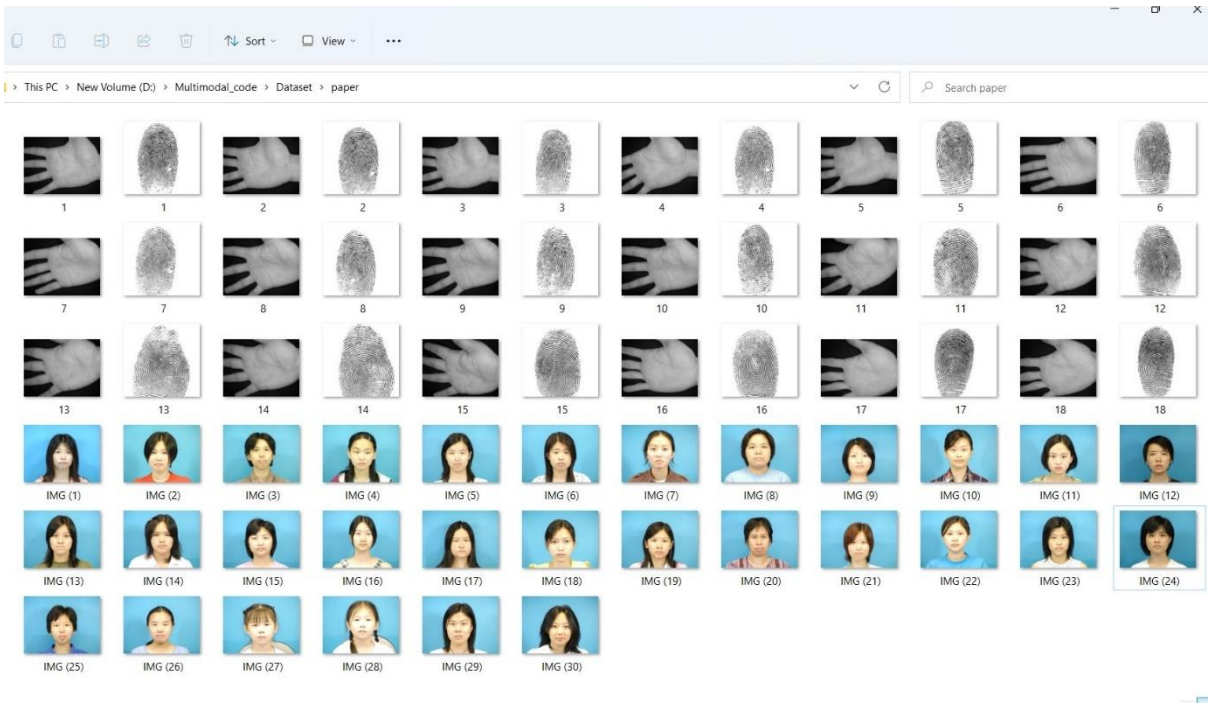

Fig. 4 Sample data of face, finger, and palm images

4.2 Pre-processing

In this step, all the sample images of the face, finger, and palm are cropped and resized properly. For the clarity of images fingerprint and palm print is converted into grayscale figure 5 indicates the resized images of the face, finger, and palm print.

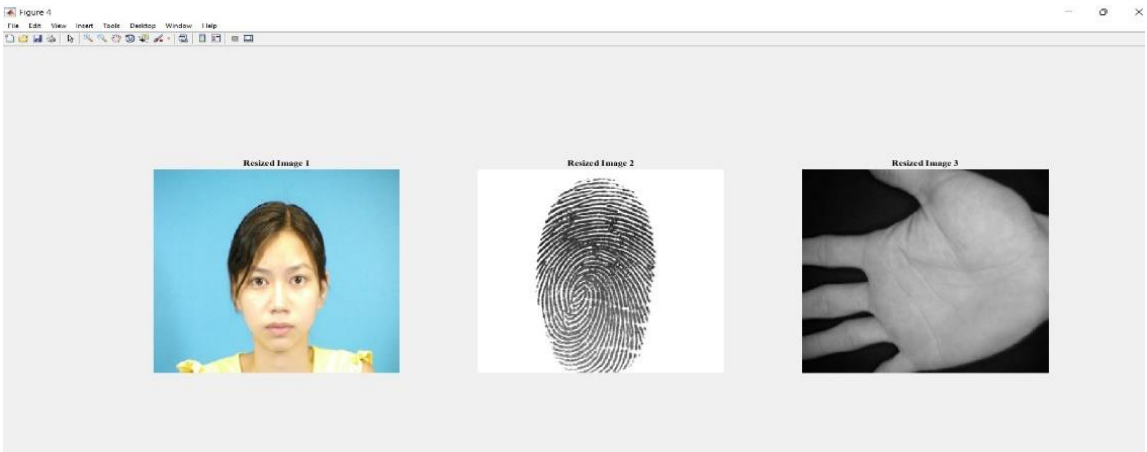

Fig.5 Resized images of the face, finger, and palm

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4.3 Segmentation

The split of finger and palm images into areas or categories that correspond to various items or parts of objects. Each pixel in an image is classified into one of these categories shown in figure 6.

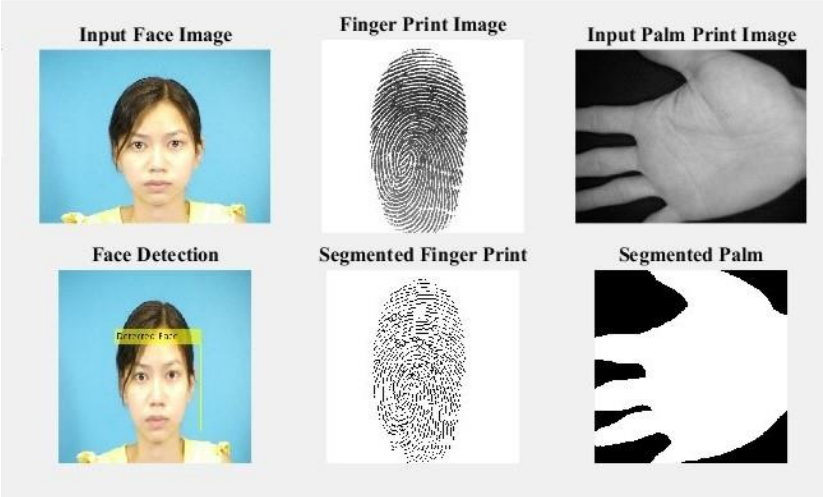

Fig.6 Segmented image of a face, finger, and palm

4.4 Feature extraction

For the face modalities, the Gaussian filter is used. it is a time-domain linear filter that is used to blur an image. It also reduces the contrast of the image by filtering out noise. For the Fingerprint and palm modality, two different feature extractors minutiae and the Harris method are used, each fused separately for further analysis. With a classification stage and an improvement stage utilizing High-Boosting filtering, the finger feature extractor uses binarization and thinniation to extract minutiae shown in figure 7 facial, finger, and palm print features of images are shown in a single-row and multiple-column metric form in figure 8.

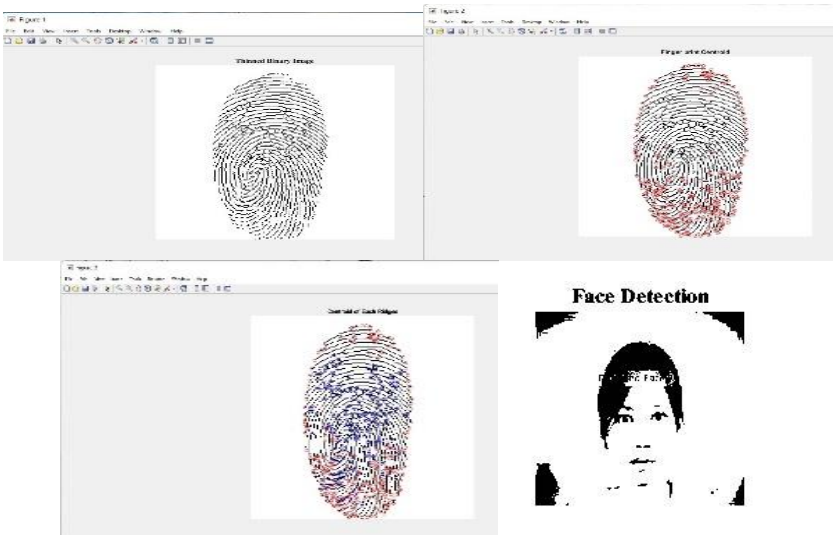

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Fig. 7 Result of minutiae Extraction and Harris method

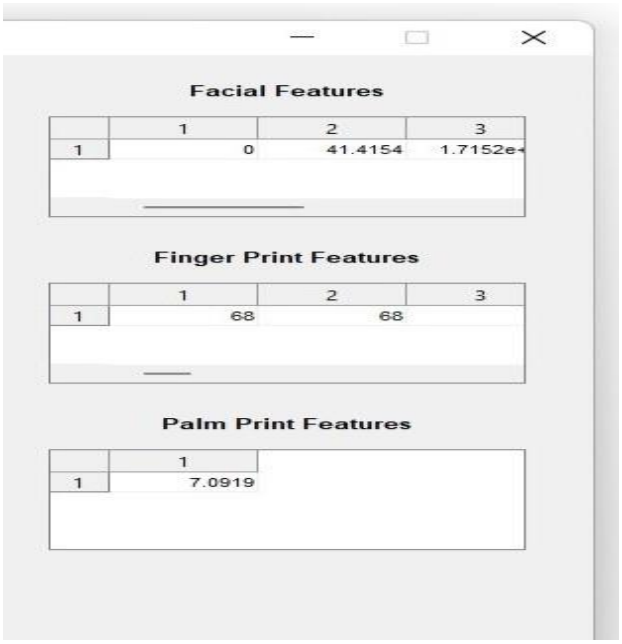
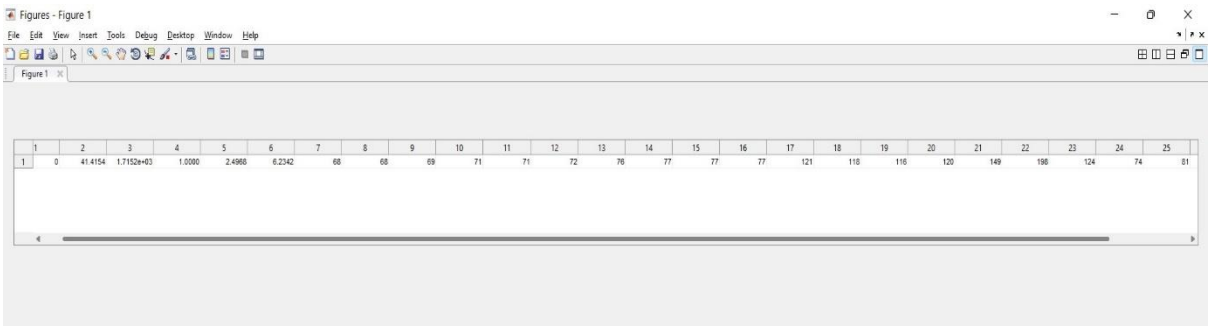


Fig.8 Features of a facial, finger, and palm print

4.5 Feature fusion

Features are extracted separately from the face, finger, and palm print images and then combine them apply the (addition operation) simple fusion approach. Figure 9 shows the result of combined features of the face, finger, and palm print.



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```
 1.0e+03 *

Columns 1 through 13

 -0.0005    0.0409    1.7147    0.0005    0.0020    0.0057    0.0675    0.0675    0.0685    0.0705    0.0705    0.0715    0.0755

Columns 14 through 26

  0.0765    0.0765    0.0765    0.1205    0.1175    0.1155    0.1195    0.1485    0.1975    0.1235    0.0735    0.0805    0.0905

Column 27

  0.0066
```

Fig. 9 The result of features fusion

4.6 Classification

If a matcher consistently offers high ratings to authentic matches while assigning extremely low values to fraudulent and fake results. As a result, it is regarded as a potent matcher. The matcher may be chosen in any way allowed by the proposed structure, as long as the matcher chosen is powerful. The extracted features of the face, finger, and palm are then matched against the template database using a principal component analysis yielding a matching result of 0 to 1.

```
--------------------------------------------------------------------------------
Observed agreement (po) = 0.9667
Random agreement (pe) = 0.0333
Agreement due to true concordance (po-pe) = 0.9333
Residual not random agreement (1-pe) = 0.9667
Cohen's kappa = 0.9655
kappa error = 0.0339
kappa C.I. (alpha = 0.0500) = 0.8991     1.0320
Maximum possible kappa, given the observed marginal frequencies = 0.9655
k observed as proportion of maximum possible = 1.0000
Perfect agreement
Variance = 0.0012      z (k/sqrt(var)) = 28.3810     p = 0.0000
Reject null hypotesis: observed agreement is not accidental

Sensitivity : 96.551724%
Specificity : 99.881094%

Correct Classification : 96.666667%
```

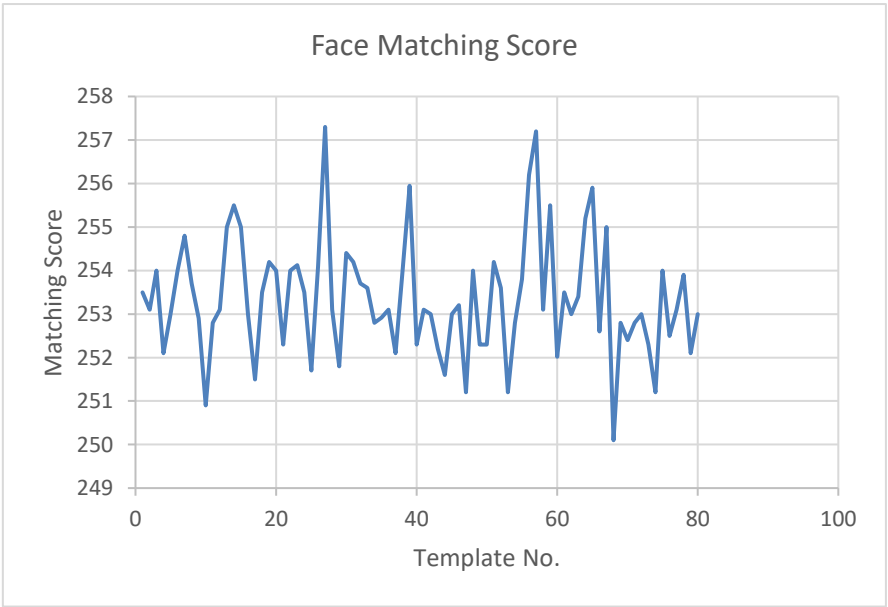

Fig.10 Face matching scores

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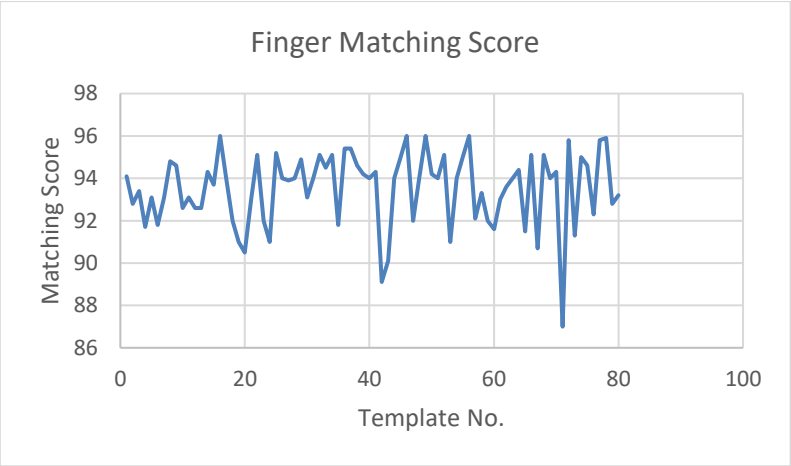

Fig.11 Finger matching scores

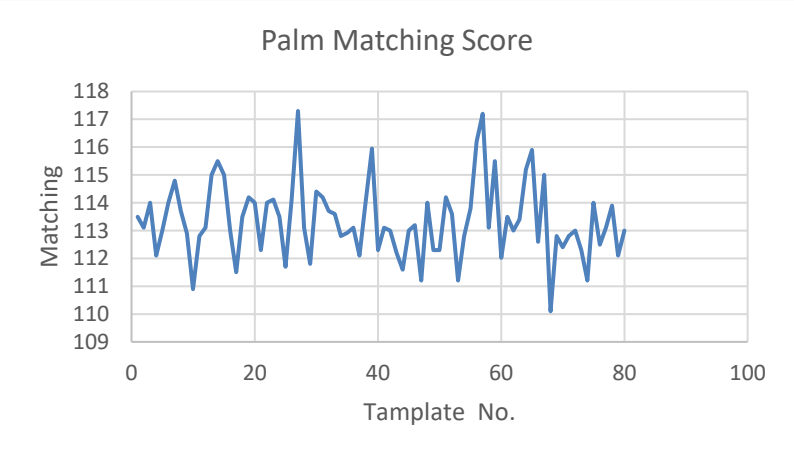

Fig.12 Palm matching scores

Figures 10 and 11 and 12 illustrate the matching scores for the face modality, Fingerprint modality, and palm modality, respectively.

4.7 Performance evolution

The sort of fusion algorithm/approach to utilize is unrestricted. Here, a basic accumulator-based fusion method is used. Because three modalities employ the same matcher, the resulting finding rates are equivalent and hence straightforward to gather. Because it takes advantage of the strong matcher's feature, this simple accumulator can produce results that are comparable to the classic technique. While both modalities produce incorrect results and the greatest possible score for distinct patterns, the genuine matching value remains relatively high. As a result, the accurate match score will be higher if the matching scores of three different modalities are added together. The cumulative scores are shown in Figure 13, and it can be seen that the actual template generates the highest score.

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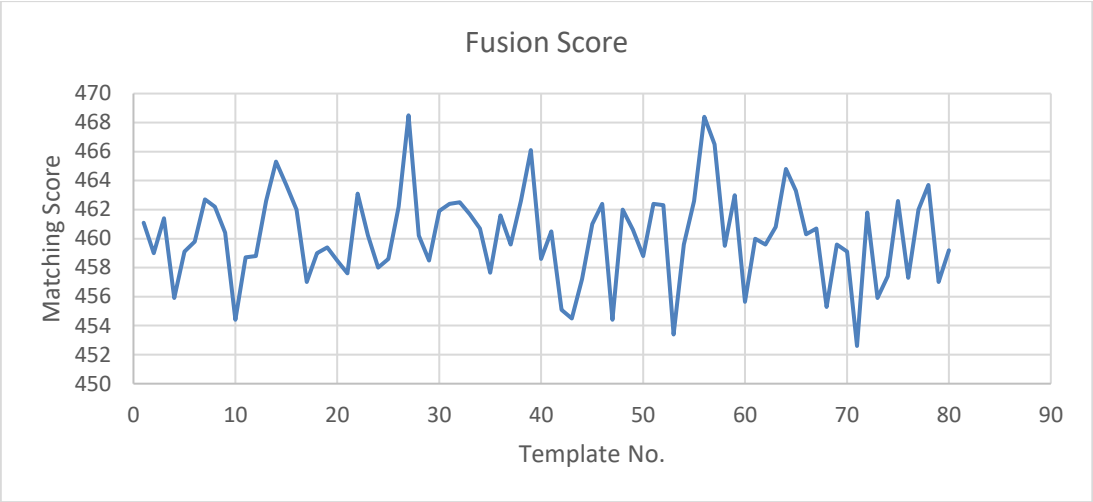

Fig. 13 Fused score

The highest perfectly matched values from each person's four enrolment pictures are then thresholded to determine the genuine vs. imposter judgment. The Equal Error Rate is used as the threshold (ERR). Whereas if the matching value reaches the threshold, the authentication is done as legitimate. If somehow the corresponding score falls below the threshold and when more than one enrolment set gives the highest score, the user is identified as an impostor. The outputs of both the unimodal and fused systems are evaluated using the same decision scheme.

This dataset is used to evaluate three different multimodal fusion systems, each with a separate face feature extractor, fingerprint feature extractor, and palmprint feature extractor. We evaluate the raw data from three individuals with the raw results from one individual. The findings of this experiment are listed in Table 1.

Table 1. Unimodal and multimodal experimental results

	Genuine	Imposter	FAR	FRR
Face	60	10	15	15
Finger	65	9	13	13
Palm	63	9	14	14
Face+Finger	72	10	9	9
Finger+Palm	73	9	9	9
Face+Palm	75	9	8	8
Face+Finger+Palm	80	8	6	6

This comparison is made to show that the proposed system produces better results than the individual comprising a unimodal system. The results indicate a notable increase in efficiency and a very significant decrease inside this Equal Error Rate.

Table 2. Comparison between % improvement in ERR

	Fused Score	EER % improvement
Face + Finger	6	44.52 %
Finger + Palm	10	41.17 %
Face + Palm	7	47.31 %
Face + Finger + Palm	9	40.00 %

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As a result, rather than comparing absolute ERR values, we compare the percentage growth in ERR in Table 2. Table 1 displays the separate ERR numbers, the fused ERR value, and the percentage improvement in ERR, as well as the findings.

The findings indicate categorically that the proposed model delivers comparable results to the conventional technique of integrating the top three unimodal systems.

5. Conclusion

The structure is meant to be extremely versatile, allowing the developer to select not just the biometric characteristic of interest, but rather the feature extractors and matches. This article aims to demonstrate the feasibility of a multimodal biometric authentication system based on a single matcher. Face, fingerprint, and palm modalities are used to verify the framework. The suggested framework is low-cost, has a tiny memory footprint, and is simple to implement on hardware. Notably, the framework's flexibility and openness, which enable easy adjustability of multiple different classifiers and matches, contribute to the system's plug-and-play aspect. One of the most notable consequences of employing this framework is that it forces the designer to consider fusion from the start and to pay close attention to the development of the feature extractors.

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