Design and evaluation of multimodal biometric system with fingerprint and face recognition

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Abstract- Biometric systems are getting popularity since last decade. As per the demand of IT industry, this technology is satisfying authentication and authorization needs. But Unimodal Biometric systems have their own limitations. To overcome the limitations of Unimodal Biometric Systems, we can choose the approach of Multimodal Biometric Systems. In this paper, researchers have given details about Multimodal Biometric system designed and developed to improve success ratio of authentication. They have adapted fingerprint and face recognition methods with match score level fusion. We have tried to identify success ration under various combinations of weights assigned to fingerprint and face match scores.

Index Terms- fingerprint recognition, face recognition, multimodal biometric system, match score level fusion

I. Introduction

A. Biometrics

This is the era of information technology. With increasing span of utilization of information technology, it is required to maintain security of resources and managing identity of users. For this purpose, many methods are there in use. But out of that, Biometric technologies have proved their superiority among all the techniques. The following are the benefits of using Biometric systems for the purpose of authentication and authorization:

- **a.** Robustness: Over time, the characteristic should not change (Permanence), and thus have low intra-class variability.
- **b.** Distinctiveness: Over the population, a great variation of the characteristic should exist (Uniqueness), and thus have large inter-class variability.
- **c.** Availability: Ideally, the whole population should possess the characteristic (Universality).
- **d.** Accessibility: The characteristic should be easy to acquire (Collectability).

B. Various unimodal biometric techniques

Biometric technologies can be divided in two categories:

a. Physiological
b. Behavioral

Physiological Biometric traits are stable for the human being. Under few circumstances, there may be change in physiological traits, but it's rare. They are more proven compare to Behavioral Biometric traits [1]. The example physiological biometric traits are:

a. Fingerprint
b. Face
c. Retina
d. Iris
e. Hand geometry
f. DNA
g. Palmprint

Behavioral Biometric traits on the other hand depend on human behavior. So they can not be as much stable as Physiological traits. The example Behavioral Biometric traits are:

a. Voice
b. Signature
c. Keystroke
d. Gait

Out of all these techniques, fingerprint and face recognition are the oldest biometric traits. These technologies have become mature with time span. At the same time, techniques like iris and retina have proven their best recognition rate among all.

C. Limitations of unimodal biometric techniques

As we have seen number of physiological and behavioral biometric techniques, these techniques have their own limitations. These limitations are:

a. Noisy sensor data
b. Non-universality
c. Lack of individuality
d. Lack of invariant representation
e. Susceptibility to circumvention

The above mentioned limitations affect the performance of unimodal biometric traits. These limitations can be resolved by introducing Multibiometric systems.

D. Multibiometrics

Multibiometric systems can be designed in different ways. Following are the types of multibiometric systems [2]:

a. Multi-algorithm systems – the same biometric data processed with different algorithms
b. Multi-sensor systems – the single biometric trait imaged using multiple sensors
c. Multi-instance systems – use of multiple instances of same biometric trait
d. Multi-sample systems – a single sensor used to get multiple samples of same biometric trait
e. Multi-modal systems – use of the evidences collected from multiple trait

First four methods can be implemented with single biometric trait and with multiple algorithm or sample or sensor or instance. But if we consider the last one i.e. Multimodal system, then we require using multiple biometric traits for authentication. It is one of the most successful techniques among all.

II. MULTIMODAL BIOMETRIC SYSTEMS

Multimodal biometric system can be considered more reliable due to presence of multiple biometric traits to be used for authentication or authorization purpose. These systems can meet strict performance requirements imposed by different applications. These kinds of systems require improving speed and reliability of biometric authentication by integrating scores of different modalities. Varieties of fusion techniques are available for this purpose. They are: majority voting, sum and product rules, k-NN classifiers, SVMs, decision trees, Bayesian methods, etc. [3]. Let us have look at few examples of multimodal biometric systems in Table 1:

Modalities fused	Authors	Level of fusion	Fusion methodology
Face and voice	Brunelli and Falavigana, 1995	Match score and rank	Geometric weighted average; HyperBF
Face, voice and lip movement	Frischholz and Dieckmann, 2000	Match score, decision	Weighted sum rule, majority voting
Face and fingerprint	Hong and Jain, 1998	Match score	Product rule
Face, fingerprint and hand geometry	Ross and Jain, 2003	Match score	Sum rule, decision trees, discriminant function
Face, fingerprint and voice	Jain et al., 199b	Match score	Likelihood ratio
Face and iris	Wand et al., 2003	Match score	Sum rule, weighted sum rule, fisher's linear discrimination , neural network
Face and gait	Shakhnarovich et al.,	Match score	Sum rule
Face and ear	Chang et al., 2003	Sensor	Concatenation of raw images
Face and palmprint	Feng et al., 2004	Feature	Feature concatenation
Fingerprint, hand geometry and voice	Toh et al., 2004	Match score	Weighted sum rule
Fingerprint and hand geometry	Toh et al., 2003	Match score	Reduced multivariate polynomial model
Fingerprint and voice	Toh and Yau,2005	Match score	Functional link network
Fingerprint and signature	Fierrez-aguilar et. al.,2005c	Match score	SVM in which quality measures are incorporated
Voice and signature	Krawczyak and Jain,2005	Match score	Weighted sum rule

Table 1. Various multimodal biometric system implementations

III. DIFFERENT FUSION TECHNIQUES FOR MULTIMODAL BIOMETRIC SYSTEMS

Fusion in multimodal biometric systems can be done in two different ways:

a. Fusion prior matching
b. Fusion after matching

A. Fusion prior matching

Fusion prior to matching can be achieved with two methods:

a. Sensor level fusion
b. Feature level fusion

Sensor level fusion is applicable if multiple sources of single biometric trait are used to collect different samples.

Feature level fusion is done by combining different feature sets collected from multiple biometric sources. Features sets can homogeneous or heterogeneous. The consolidation sometimes can also create problems as feature sets are collected by using different algorithms or modalities.

B. Fusion after matching

Fusion after matching can be achieved with three different ways:

a. Match score level fusion
b. Rank level fusion
c. Decision level fusion

Match score level fusion is method providing richest set of information. It is one of the widely used methods for fusion. Match score level fusion in turn can be achieved with three different ways:

a. Density based score fusion
b. Transformation based score fusion
c. Classifier based score fusion

Rank level fusion consolidates ranks output given by different subsystems for different modalities. Consolidated rank is generated for each identity. This method provides less information compare to match score level fusion.

Decision level fusion is the weakest method of fusion. It is carried out at decision level when outputs by different matchers are available. Decisions are evaluated with the help of the rule like 'AND' or 'OR', majority voting and Bayesian decision fusion etc.

In our experiments, we have taken the approach of multimodal biometric authentication with match score level fusion by using fingerprint and face recognition.

IV. SUGGESTED MULTIMODAL BIOMETRUC SYSTEM WITH FINGERPRINT AND FACE RECOGNITION

The researcher has designed the GUI for proposed multimodal biometric system shown in Figure 1. For the purpose of face recognition and fingerprint recognition, COTS tools have been used. This code is open source and is accessible to all.

For the purpose of face recognition, PCA based Eigenface method has been used. The details are given in [4]. The code was developed by Amir Hossein Omidvarnia in MATLAB in 2007. He implemented PCA based face recognition method with Eigenface by considering [5].

For the purpose of fingerprint recognition, Minutiae based method has been adopted. The code was developed by Vahid. K. Alilou in MATLAB. He took the reference of [6] for the development of fingerprint recognition system.

The process contains following steps:

1. Load face test sample
2. Load fingerprint test sample
3. Compare face test sample with train database samples and write matching score of each comparison in a vector.
4. Compare fingerprint test sample with train database samples and write matching score of each comparison in text file.
5. Read the vector of matching scores of face recognition and normalize score as it has float values. The resulting normalized value will be in the range of [-1,1]. The following method has been used for score normalization:
    a. Calculate sum of all vector values (Euclidian distance)
    b. Calculate average Euclidian distance
    c. Calculate difference between average Euclidian distance and all other distances.
    d. Divide each difference with average Euclidian distance and get value in the range of [-1,1].
6. At this stage we have both the scores in normalized form.
7. Ask for face weight and fingerprint weight in the range of 0.1 to 0.9. Total of both weights must be 1.
8. Multiply each face and fingerprint normalized score with respective weights and make sum of both values.
9. Find the maximum matching score and get index of that sample
10. Display highest matching score and index of that score in GUI.

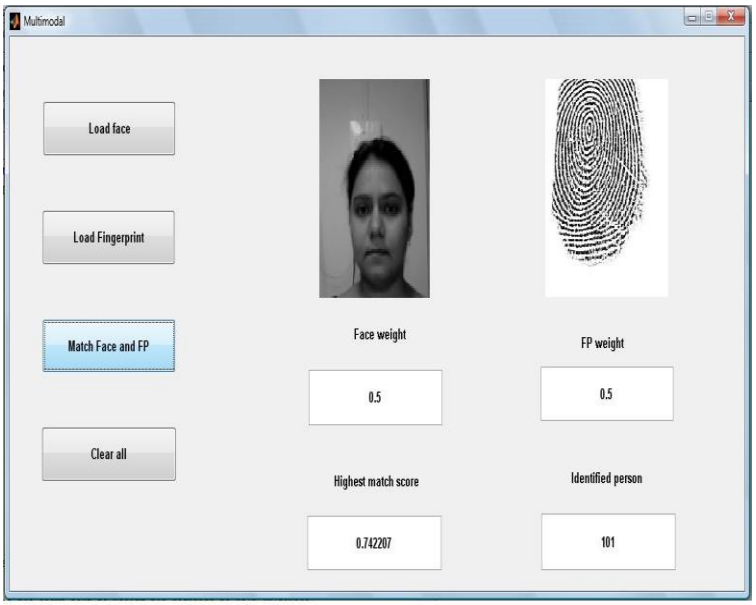

Figure 1. Suggested system for multimodal biometric authentication

V. EXPERIMENTAL RESULTS

The experiments were applied with test database of 30 samples of 30 people. The train face database contains 60 samples of 30 people (2 for each). The train fingerprint database contains 30 samples (One for each person). Here we have used match score level fusion as we have already mentioned previously that it has the richest information set.

The other makeable thing is the use of weights for faces and fingerprint scores. We have applied different combinations of weights ranging from 0.1 to 0.9 for each modality. The results of the designed system are shown below in Table 2:

faceweight	fpweight	Success	Failure	Success rate (GAR)	Failure rate (FRR)
0.1	0.9	28	2	93.33	6.67
0.2	0.8	27	3	90.00	10.00
0.3	0.7	27	3	90.00	10.00
0.4	0.6	28	2	93.33	6.67
0.5	0.5	26	4	86.67	13.33
0.6	0.4	25	5	83.33	16.67
0.7	0.3	25	5	83.33	16.67
0.8	0.2	25	5	83.33	16.67
0.9	0.1	24	6	80.00	20.00

Table 2. Experimental results of multimodal biometric system

The following Figure 2 shows trend in performance based on weight distribution among both the modalities:

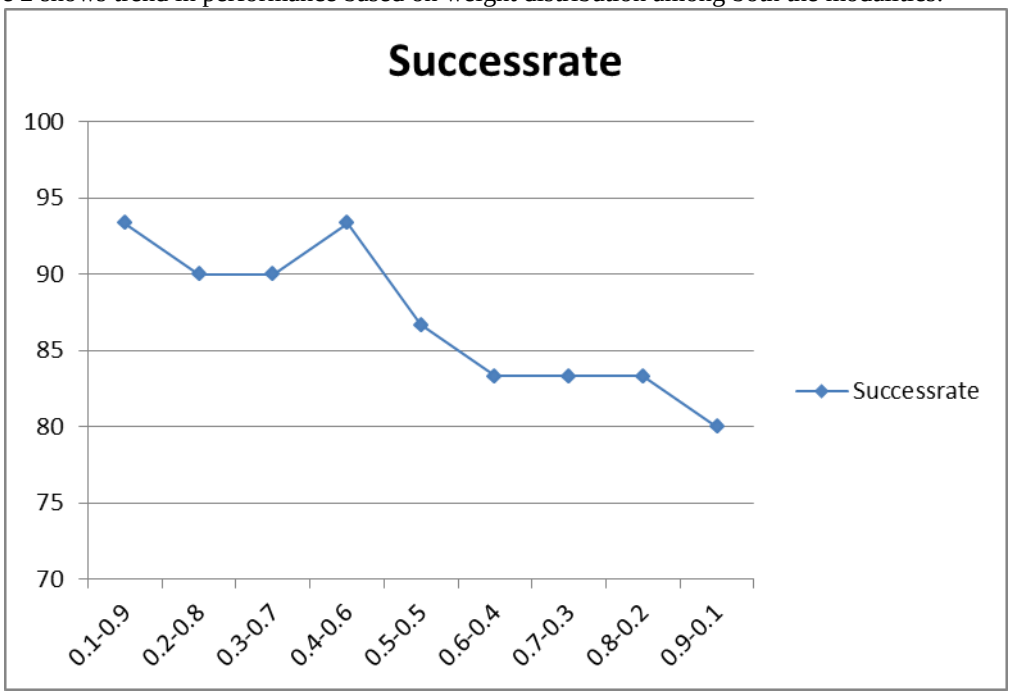

Figure 2. Success rate of multimodal biometric system with face and fingerprint

The results shows that when there is less weightage on face recognition, we getting acceptable success rate. But as we are increasing face weight, success rate is decreasing. For the ratio of 0.9:0.1 , we are getting 80% success rate.

VI. Conclusion

As we have seen in the experimental results that more weight on fingerprint recognition gives better results compare to face recognition. But the important thing is to identify appropriate weight distribution among different modalities. Large test database samples can be used to identify this weight distribution. Initially, we can start with equal weight distribution among both the modalities. Later based on performance, we can adjust weight distribution for face and fingerprint.

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