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An Enhanced Authentication System Using Face and Fingerprint Technologies

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Abstract: *The primary aim of this paper is to develop an enhanced authentication system using a Cascaded-Link Feed-Forward Neural Networks. In the end, the system overcomes some limitations of face recognition and fingerprint verification systems by combining both. Experimental results demonstrate that the system performs well. It meets the response time as well as the accuracy required.*
Keywords: *Multi-biometric, Face recognition, Fingerprint verification, Minutiae, pattern matching.*

I. Introduction

Biometric authentication has been receiving extensive attention over the past decade with increasing demands. Biometric is to identify individuals using physiological or behavioral characteristics, such as fingerprint, face, iris, retina, palm-print, etc. Among all the biometric techniques, fingerprint recognition [1] is the most popular method and is successfully used in many applications. Although fingerprint recognition methods have been attributed with many flaws such as users fingerprint being dirty, wet, scratches and abrasion which could lead to medical issues. Fingerprint technology employ feature-based image matching, where minutiae (i.e., ridge ending and ridge bifurcation) are extracted from the registered fingerprint image and the input fingerprint image, and the number of corresponding minutiae pairings between the two images is used to recognize a valid fingerprint image [1].The feature-based matching provides an effective way of identification for majority of people.

On the other hand, face recognition technologies is gradually taking the lead in the access control system. Most public and private places prefer face for access control and security. This has attracted the attention of vision researchers for several years. Face recognition may seem an easy task for humans, and yet computerized face recognition system still cannot achieve a completely reliable performance [2]. The difficulties arise due to large variation in facial appearance, head size, orientation and change in environment conditions. Such difficulties make face recognition one of the fundamental problems in pattern analysis. In recent years there has been a growing interest in machine recognition of faces due to potential commercial applications such as film processing, law enforcement, person identification, access control systems, etc [2,3].

Owing to the foregoing, there is therefore increasing need for an enhanced authentication system that can combine fingerprint and face. In this paper, attention is more on multi biometric to identify persons using fingerprint and face. This paper is organized as follows: General architecture of the proposed system, an Overview of fingerprint enrollment/detection. Face enrollment, detection and recognition, implementation of the proposed architecture, testing and results. Finally, some concluding remarks.

II. General architecture of the proposed system

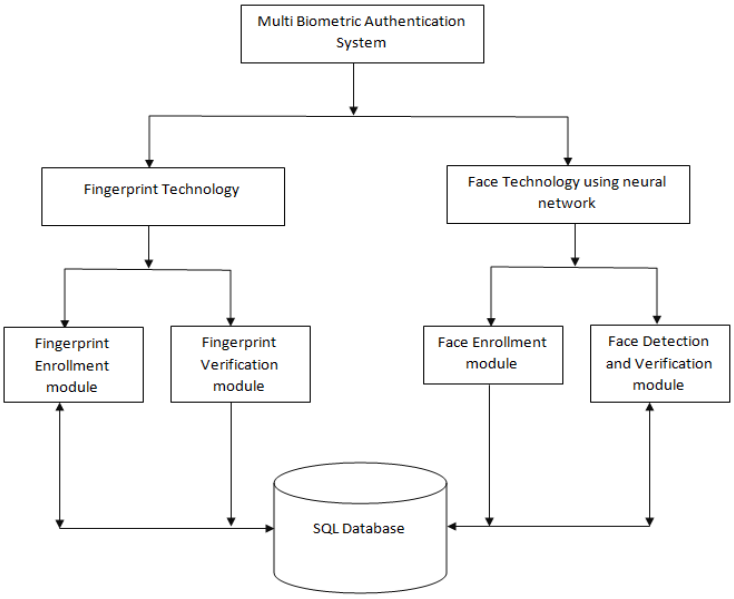


Figure 1: Architecture of enhanced Authenticatin system

The enhanced authentication system is divided into two major parts namely; the fingerprint recognition part and the face recognition part. When the application is run the user is requested to enroll his/her fingerprint for a maximum of three times through a finger print scanner in other to extract a best feature. When a best feature is extracted, it is then stored in the database for verification. In Addition, after a successful enrollment of fingerprint, the user is then prompted to enroll his/her face using either a webcam or attached camera as many as possible to capture a best quality needed. This is further stored in the database after extracting the best facial feature. This also can be done vice versa. During verification, the fingerprint scanner, webcam or attached camera is used to capture a fingerprint and a human face respectively. The captured image is extracted and further compared with the template in the database for verification. We shall now go further to discuss in details what happens in fingerprint enrollment / verification process and Face enrollment / recognition processes respectively.

III. Fingerprint enrollment/Verification

A fingerprint is presented as a series of lines which is the high line for the friction skin. We call it the ridge; as shown in Figure 2. The ridge of a fingerprint usually becomes the dark lines of a fingerprint image which is acquired by the use of the sensor device called fingerprint scanner. Between the ridges are the low lines which are the valleys. The valleys are showed as white lines in a fingerprint image. In Figure 3, some other characteristics relative to fingerprint image processing is shown. When talking about fingerprints, we often see some terms: *local, global and minutiae*. The local feature is a major representation of the ridges (the ridge endings and the ridge bifurcations, as Figure 4a and 4b), the valleys and the pores on ridges. The global features are a major representation relatives to a classification and information about locations of critical points (e.g., core and delta features, sometimes they are referred to as *singularities points*) on a fingerprint, see the descriptions as Table 2. The minutiae features are the ridge endings and the ridge bifurcation, see as Figure 5 [4] in [1].

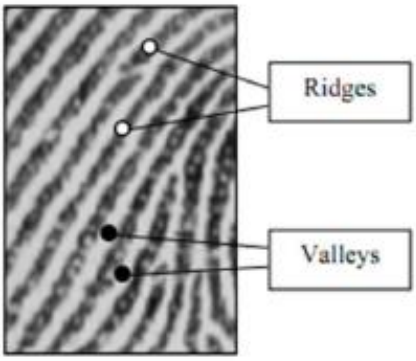


Figure 2: The ridge and valley of a finger print

Figure 3: other characteristics of fingerprint image

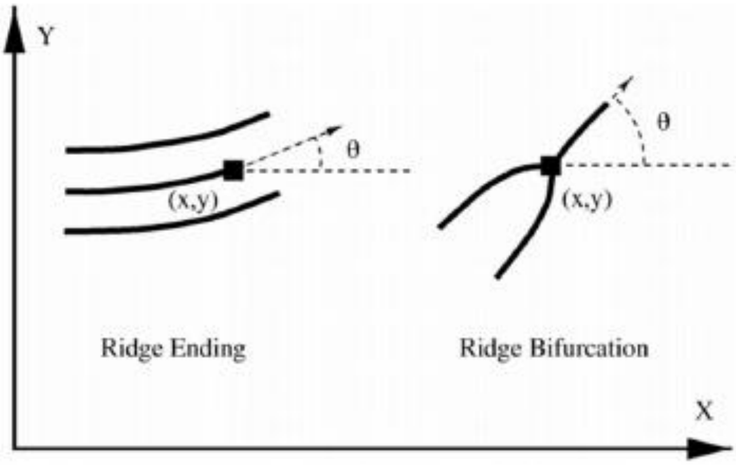


Figure 4a: The position and orientation of the ridge ending and ridge bifurcation [1]

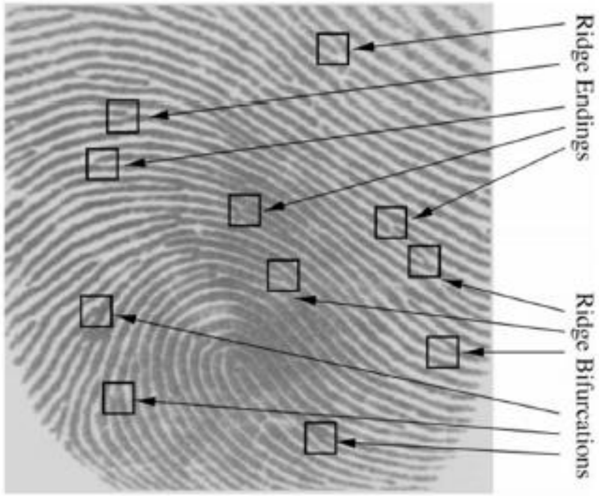


Figure 4b: Minutiae on a fingerprint [1]

1.2 Fingerprint enrollment Process

The design of the processing of the enrollment module according to the steps in Figure 5.

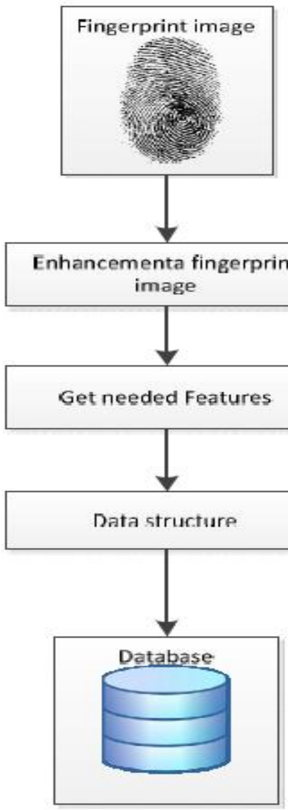


Figure 5: Fingerprint enrollment process

Step 1: **Fingerprint image**: Getting fingerprint image from the sensor device such finger print scanner.
Step2: **Enhancement of fingerprint image**: Fingerprint images that are acquired by ink or a scan sensor can include noise signals. For accurate recognition, improvement of the clarity and continuity of ridge structures is made. This is performed into 5 stages using wavelet transform; an algorithm for processing images, the stages involved are normalization, wavelet decomposition, global texture filtering, local directional compensation and wavelet reconstruction [6].
Step 3: **Get needed features**: There are some important features which are gotten from each fingerprint image. These are the center point, the class type and the features of minutiae (the location, the orientation, etc.).

Knowing the class that each fingerprint belongs on the orientation under the center point.Extraction is now made on the direction features of the lower portion of the octagon, according to Figure 6.

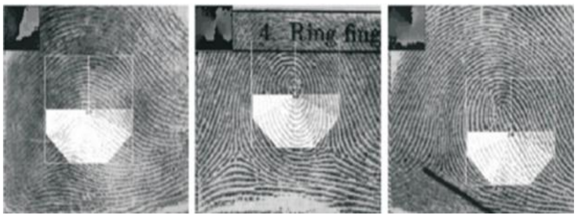
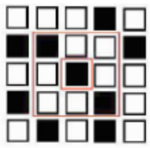
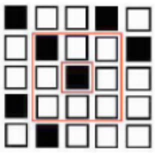
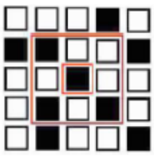


Figure 6: The portion of the octagon extracted for the direction features

Getting minutiae features is based on the thinned fingerprint image. Crossing number was used to determine a minutiae point [5]. Crossing numberis defined as half of the sum of two adjacent pixels. According to the result of crossing number, termination and bifurcation is recognized, as shown in Table 1.

Table 1: Cross number value to type of the minutiae

	Crossing number = 2 Normal ridge pixel
	Crossing number =1 Termination point
	Crossing number = 3 Bifurcation point

Step5: **Data structure**: After the needed features are gotten, the data structure for a fingerprint image is now created as shown on Figure 7.

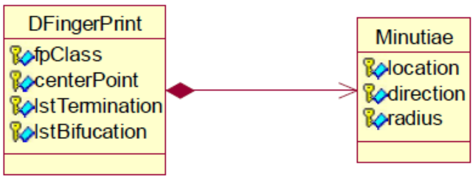


Figure 7: Data structure of fingerprint image

Step 6: **Database**: Saving the data structure of a fingerprint image into the database

3.2 Fingerprint verification process

The Fingerprint verification module uses the same representation which was used in enrollment module. The difference with the enrollment module is the matching fingerprint step, see Figure 8

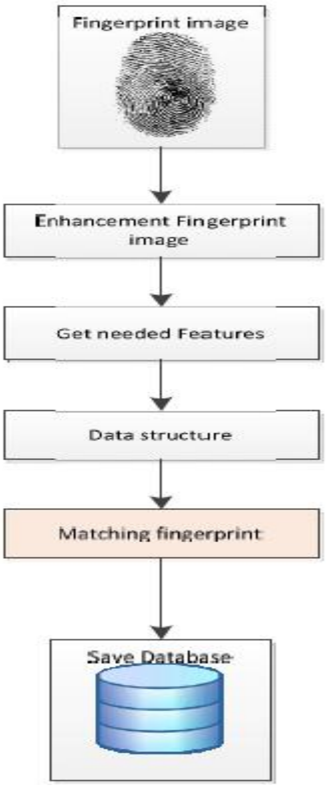


Figure 8: fingerprint verification module process

Due to the difficulty in matching a finger print, the input and template fingerprint features transform into a common frame. The transformation of the input and the template fingerprint are rotation, translation and scale. Two minutiae points are matched when they are within in the tolerance size [7, 9, 10].

For matching fingerprint, information in the fingerprint data structure is collected, involving two main steps: The first step is to limit the number of templates fingerprint by the classification value of a fingerprint image; that means a comparism of the input fingerprint with the sub template which has the same classification value with the template.The second is the comparismofeach minutiae of the input fingerprint image with each minutiae of the template fingerprint, see as Figure 9.

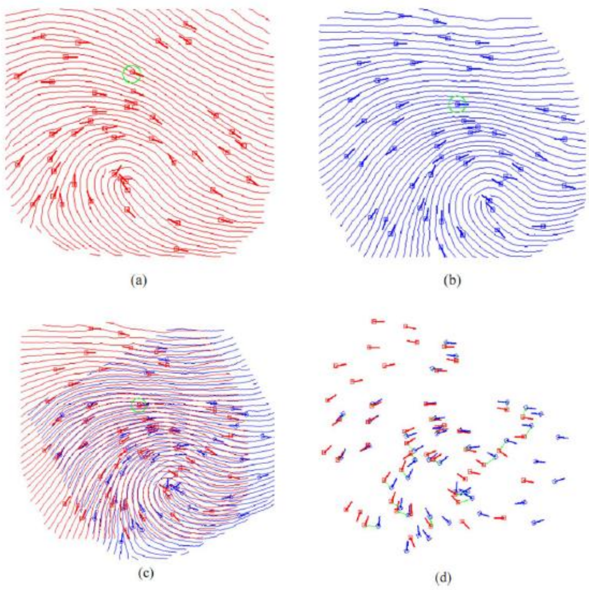


Figure 9: The processing of matching minutiae; (a)The minutiae set of the input fingerprint; (b)The minutiae set of the template fingerprint; (c)The alignment based on the minutiae of the input fingerprint and

template fingerprint; (d)the matching result where the template minutiae and their correspondences are connected [7, 1].

IV. Face detection and recognition system

The Face recognition system is made up of the following main steps: Data Preprocessing, Feature Extraction and Classification. Data Preprocessing involves steps like face detection, noise reduction, image resizing, scaling and so on. Feature Extraction involves extraction of data from the images that are relevant to face recognition and removal of any redundant data leading to reduction in size of the data set [8]. Classification will involve determining the class of the input test data based on the features extracted from the training data set. See figure 10.

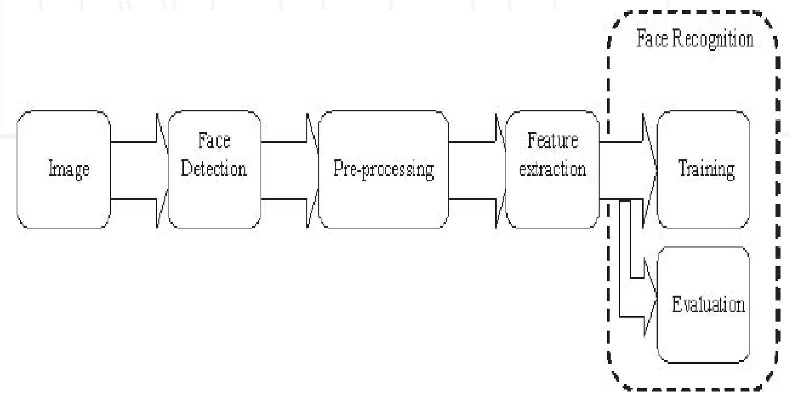


Figure 10: Architecture of the face detection and recognition system. [2]

4.1 Face detection

Face detection can be viewed as two-class recognition problem in which an image region is classified as being a "Face" or "nonFace". Consequently, face detection is one of the few attempts to recognize from images a class of objects for which there is a great deal of within-class variability. Face detection also provide interesting challenges to the underlying pattern classification and learning techniques. The class of face and no face image are decidedly characterized by multimodal distribution function and effective decision boundaries are likely to be nonlinear in the image space [11, 12]. Artificial Neural Network (ANN) Multi-Layer Perception (MLP) was employed for the face detection see figure 11.

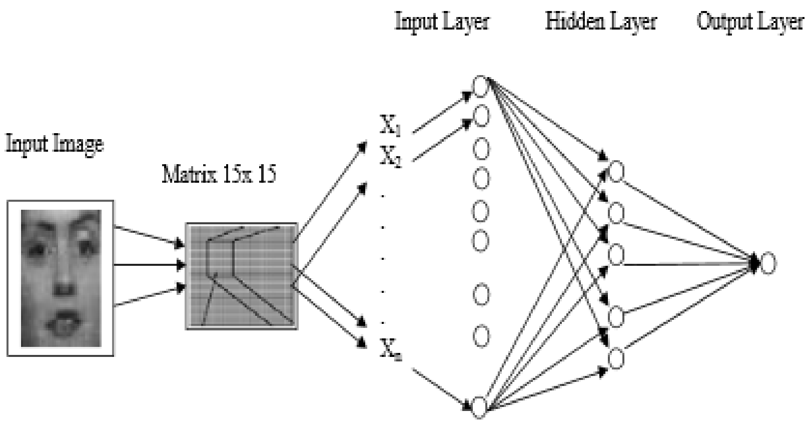


Figure 11: Face detection using neural network [2].

The MLP neural network [14] has feed-forward architecture within input layer, a hidden layer, and an output layer. The input layer of this network has *N* units for an *N* dimensional input vector. The input units are fully connected to the *I* hidden layer units, which are in turn, connected to the *J* output layers units, where *J* is the number of output classes. A Multi-Layers Perceptron (MLP) is a particular kind of artificial neural network [13]. Assuming that there is access to a training dataset of *l* pairs (xi, yi) where xi is a vector containing the pattern, while yiis the class of the corresponding pattern. In this case a 2-class task, yicanbe coded 1 and -1. In the proposed system, the dimension of the retina is 15x15 pixels representing human faces and non-face, the input vector is constituted by 225 neurons, the hidden layer has 15 neurons [12, 13].

1.3 Pre processing

The appearance of the face varies due to relative camera-face pose, between full frontal images and side-profile images; in-situ occlusions such as facial hair (e.g.beard, moustache), eye-glasses and make-up; facial expressions can significantly influence the appearance of a face image; overlapping occlusions where faces are partially occluded by other faces present in the picture or by objects such as hats, or fans; conditions of image acquisition where the quality of the picture, camera characteristics and in particular the illumination conditions can strongly influence the appearance of a face. For better system performance, in the recognition stage, a set of pre-processing techniques was applied: the first step in pre-processing is to bring all images into the same color space and to normalize the size of face regions. This normalization process is critical to improving the final face recognition rate and some experimental results will be presented in the later [15,16,17].

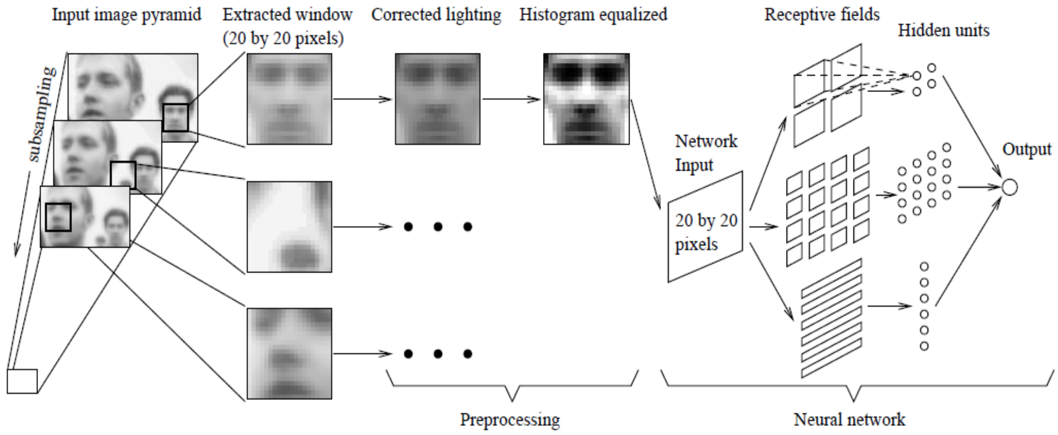


Figure 12: Face detection showing preprocessing stage using neural network [12].

4.3 Feature extraction

The feature extraction technique used is implemented by scanning the image with a fixed-size window from left-to-right and top-to-bottom. A window of dimensions $h \times w$ pixels begins scanning each extracted face region from the left top corner sub-dividing the image into a set number of $h \times w$ sized blocks. On each of these blocks a transformation is applied to extract the characterizing features which represent the observation vector for that particular region. Then the scanning window moves towards right with a step-size of n pixels allowing an overlap of o pixels, where $o = w - n$. Again features are extracted from the new block. The process continues until the scanning window reaches the right margin of the image. When the scanning window reaches the right margin for the first row of scanned blocks, it moves back to the left margin and down with m pixels allowing an overlap of v pixels vertically. The horizontal scanning process is resumed and a second row of blocks results, and from each of these blocks an observation vector is extracted [18,19,20,21,22]. The scanning process and extraction of blocks is shown on Figure 12.

Figure 13: Block extraction from a face image.

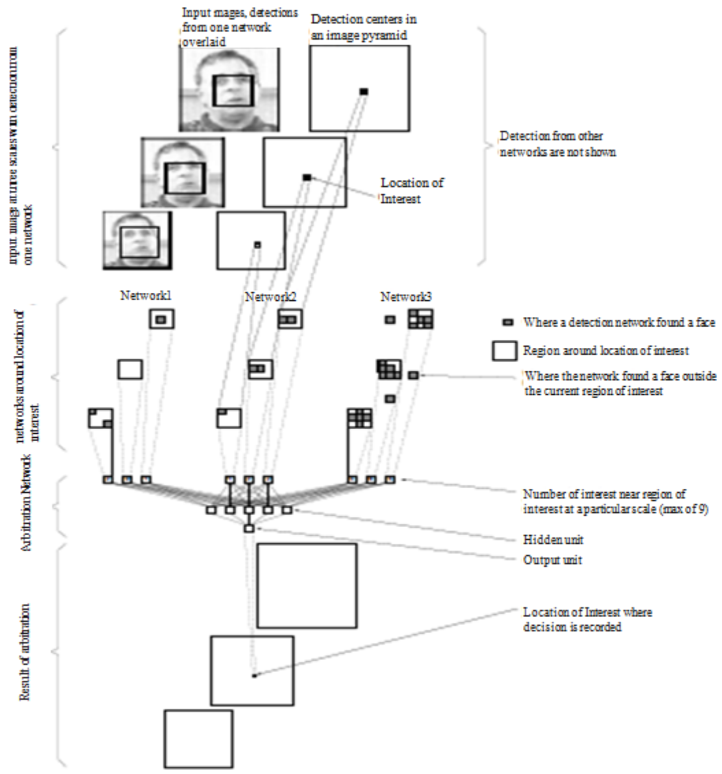


Figure 14: Feature extraction from a face image using neural network [12].

4.4.1 Face Recognition
4.4.2 Training

Multi-Layer Perceptron (MLP) with a back propagation learning algorithms was chosen for the proposed system because of its simplicity and its capability in supervised pattern matching. It has been successfully applied to many pattern classification problems [11]. The problem has been considered to be suitable with the supervised rule since the pairs of input-output are available. For training the network, the classical back propagation algorithm was used. An example is picked from the training set, the output is computed. The error is calculated as the difference between the actual and the desired output. It is minimized by back-propagating it and by adjusting the weights. Although back-propagation can be applied to network with any number of layers, it has been shown that one layer of hidden units suffices to approximate any function [11,13,14]. Therefore, in most application, a MLP Neural Networks (NN) with a single layer of hidden units is used with a sigmoid activation function for unit $f\,(a)=\frac{1}{1+e^{-a}}$. This function has the interesting property of having an easy to compute derivative $f'(a) = f(a)[1 - f(a)]$. The MLP training is amount to: repeatedly presented with sample inputs and desired targets. Then the output and targets are compared and the error measured. At last, adjusts weights until correct output for every input.

4.4.3 Evaluation

In the evaluation process, a model of a newly acquired test subject iscompared against all existing models in the database and the most closely correspondingmodel is determined. If these are sufficiently close, a recognition event is triggered [2].

V. Implementation

The system was implemented using vb.net on a visual studio 2010 and MySQL as relational database. At first the neural network architecture was created and then trained with training set of faces and non-faces. In neural network architecture some functions are used for training purpose (training function trainscg ()), initialization purpose (Layer Initialization Functions initnw()), and for performance purpose (Performance Functions msereg ()) etc. In the face detection algorithms Fast Fourier transform are used with training function trainscg() [13,23,]

VI. Testing and results

6.1 Testing

Different faces and fingerprints were used to assess the performance of the system. For each person, one fingerprint with acceptable quality was selected as the template. All but one face images were used to train the face recognition subsystem. The remaining face image was paired with the fingerprint to form a test sample. This process was repeated several times. An example of the identification is shown on figure 13a and 13b

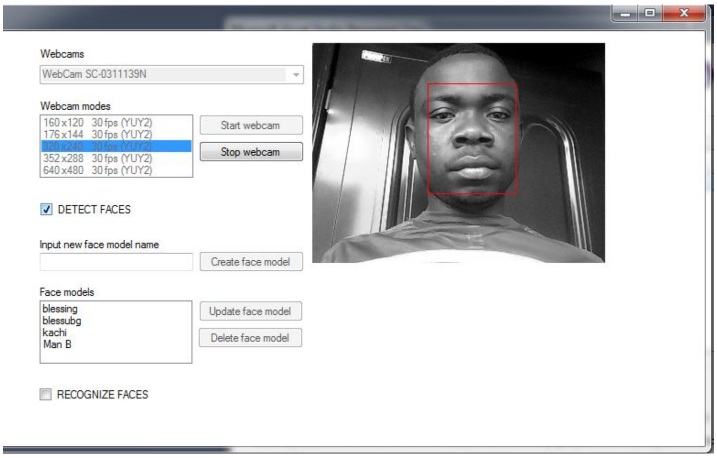


Figure 15a Face Image acquisition and identification

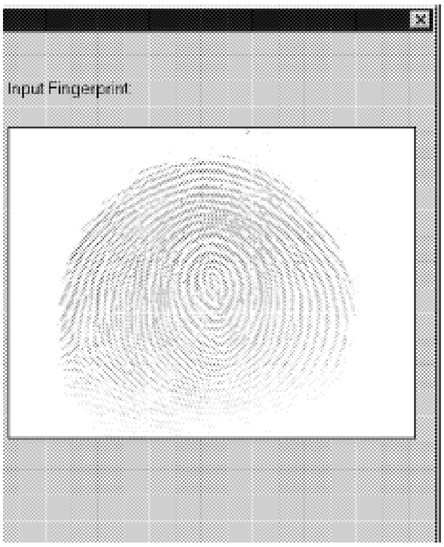


Figure 15b fingerprint Image acquisition

1.4 Results

The identification accuracy of the integrated system as well as identification accuracies of face recognition and fingerprint identification is compiled in table 1. The response time of the integrated system for a typical identification is 3 seconds see table 2. In comparison, identification using only fingerprints on a database of 5 persons takes 9 seconds. From this, the system can achieve desirable identification accuracy with an acceptable response time. This was developed and run on a machine with following configuration; Intel core i5 2.5 GHZ processor with window 7 32bit operating system, 2 GB RAM.

Table 1: Identification accuracy of face recognition and fingerprint identification

No of Faces	No of fingerprints	No of faces detected at each compare	No of fingerprints detected at each compare	Accuracy (%)
5	5	1	1	100

Table 2: Response time of the system

Face location (Seconds)	Face Retrieval (Seconds)	Fingerprint Verification (Seconds)	Total (Seconds)
0.5	0.5	2.0	3.0

VII. Conclusion

This system has successfully integrated and implemented face and fingerprint technologies for personal identification. The system overcomes some limitations of face recognition and fingerprint verification systems. Experimental results demonstrate that the system performs well. It meets the response time as well as the accuracy required.

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