Multi-biometric Face Recognition System using Levels of Fusion.

Elizabeth Garcia-Rios, Enrique Escamilla-Hernandez, Gualberto Aguilar-Torres, Omar Jacobo-Sanchez, Mariko Nakano-Miyatake and Hector Perez-Meana

***Abstract*—**This paper proposes the implemental of a Multi-biometric face recognition system based on levels of fusion using stereo images. Only three fusion levels are used for developing the proposed face recognition system which are; sensor level fusion, feature level fusion and decision level fusion; where for each level of fusion was used the Eigenfaces and Gabor Filters for the feature extraction while for data classification the back propagation neural network and Support Vector Machine are used. At each level of fusion it is possible to evaluate the performance of proposed face recognition marking the highest identification and verification rate. Giving the best result the feature level fusion that consist of two images with different angles of face, because with this we get more coefficients or information that constitute a new template of the face. This provides a higher recognition rate in comparison with the systems that use a picture with a single angle. Also was observed the system behavior with different features extraction and classification algorithms. Evaluation results show that the best results are obtained using the Gabor filters with the Support Vector Machine, because in this case the recognition rates are higher and with less computation time.

***Keywords*—**Multi-biometric system, levels of fusion, Eigenfaces, Gabor filters, Neural Network Back propagation, Support Vector Machine.

I. Introduction

A biometric system is essentially a pattern recognition system that acquires biometric data from an individual, extracts a salient feature set from these data, compares these features set with the feature sets stored in the database and executes an action based on the result of such comparison. These systems perform, basically, two tasks: identification and identity verification [1]. In the first one the goal is to determine the person most likely to be among a set of persons, while in the second one to verify if the person is who he/she claims to be, in both bases, based on the physical (face, fingerprint, iris, voice, etc.) or behavioral features (signature, dynamic typing, way of walking, etc.) of the people under analysis [1], [2].

Among the biometric systems, the face is one of the most widely used, because it is a non-intrusive method and where the facial attributes, like; eyes, eyebrows, nose, lips and skin, which are the main features used to make a personal recognition are capture by a camera [3]-[9].

Face recognition has received significant attention in the last several years because it is increasingly being used in many commercial applications due to the rapid electronic technology evolution. As a result several efficient algorithms have been proposed during the last two decades and many of them are even currently available on the market. However almost all still require some special conditions for its optimal operation such as: the pose and orientation of face, background lighting and diverse face expressions. Also the quality of input image is very important because, if the image face is noisy, poorly captured or presents large occluded regions, the subsequent process may be severely affected and as a consequence, the recognition rates may become lower. Therefore it is important to obtain an input image containing as much information as possible in order to have a better assessment of the face characteristics [10]

Other limitations of most face recognition systems, which has received little attention, is the fact that the face is a three dimensional object and most currently proposed face recognition systems are based on two dimensions images [4]-[9] which may be cheated by placing a photo of another person in front of the input camera. To avoid this problem, this paper proposes a face recognition system which uses stereo images of face, doing the fusion of this information, for improving the precision of a face recognition system**.** At entrance, the system captures stereo images which are firstly used to determine in the captures images corresponds to a three dimensional object or a two dimensional picture. Next different three different levels of fusion as analyzed such as: sensor level fusion, feature level fusion and decision level fusion. The usage of these levels of fusion is with two components of stereo image in an individual form, combining them to form a 3-dimensional face model. To develop the feature extraction stage two efficient methods are used: the eigenfaces [3], [7] and Gabor filters [7]-[9] methods. Finally in the classification stage the methods are analyzed: the Back-propagation neural network [1], [7], [11] and the Support Vector Machine [9]-[15]. The experimental results show that the proposed multi-biometric system overcomes some of the limitations present in an

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unimodal biometric system, by consolidating the evidence presented by multiple biometric sources. Analyzing each level of fusion it follows that, although the three levels of fusion, in most cases improves the identification and verification rates the feature level fusion, making the arithmetic mean of two features vectors obtained from the face, provides the highest match score. This data integration enhances the matching accuracy of a recognition system. Thus, working on with a multi-biometric system and using stereo vision reduces the probability of spoofing identity.

II. Proposed Face Recognition System

The proposed face recognition system consists of the image acquisition stage which captures two stereo images obtained from a camera with two lenses or by two cameras. These images are then cut for delete the useless information that might affect the system. Next, both images are analyzed to determine if they corresponds to a three dimensional face or to a two dimensional image. If the images correspond to an actual face, depending on the level fusion used, the feature extraction module obtains one or two feature vectors that contain the significant information using both face images. Then, this information is compared in order to find a match, with the computed information from the database. And finally is taken the decision for the identification of the person.

A. Preprocessing Stage

Stereo vision has the ability to recover the three dimensional structure of a scene from at two different images taken from different angles, if the distance between both cameras is known. Recovering the structure is the position of the objects in the scene essentially the depth or distance between the observer and the objects [16]. Thus in stereo vision, as shown in Fig. 1, two cameras displaced horizontally one from the another one are used to obtain two differing views on a scene, in a similar manner than human binocular vision. Comparing these two images is possible obtained the depth information of object and then determine if the images under analysis corresponds to a three-dimensional face, or they corresponds to a bi-dimensional images. This fact reduces the wrong decisions of a face recognition system when at as input are provided two pictures of a bi-dimensional image face, instead of two stereo pictures of a real there dimensional face.

A simple scheme that may be used for this purpose is shown in Fig. 2. Here firstly, both the left and right pictures are converted to the image format YCbCr and HSI to obtain the luminance and intensity components. Next the Intensity components of both images are overlapped, obtaining the mean value of the difference among them. The same operation is carried out using the intensity value of both images. The main idea behind this approach is the fact that, the difference between the luminance and intensity of both images of a 3D face is large, because the disparity present between both images. On the other hand the difference between the luminance and intensity of right and left images took form a 2D picture is low because both images are almost the same. Thus if the estimated values are larger than a given threshold the image is consider as a picture of a 3D face, otherwise it is considered as a picture of a 2D image and then the recognition process is stopped. Figures 3-5 show the differences between the images obtained from a real 3D face those obtained from a 2D picture.

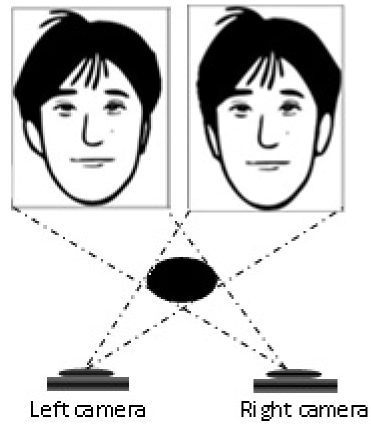

Fig. 1 Stereo vision with two cameras

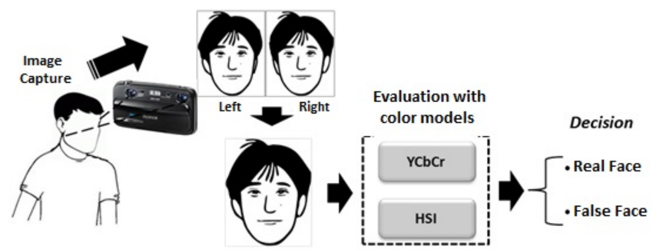

Fig.2 Proposed scheme used for discriminating image obtaining form a real 3D face, from a picture obtained form 2D picture.

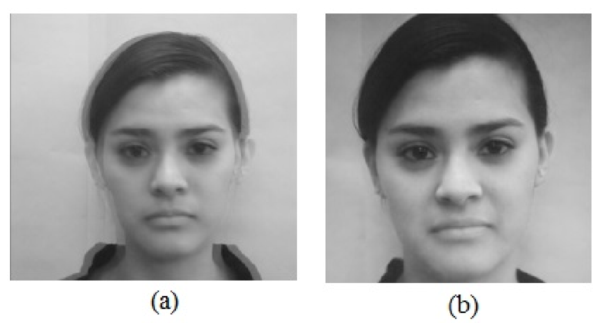

Fig. 3 Overlapped images from (a) a real 3D face, (b) a 2D picture.

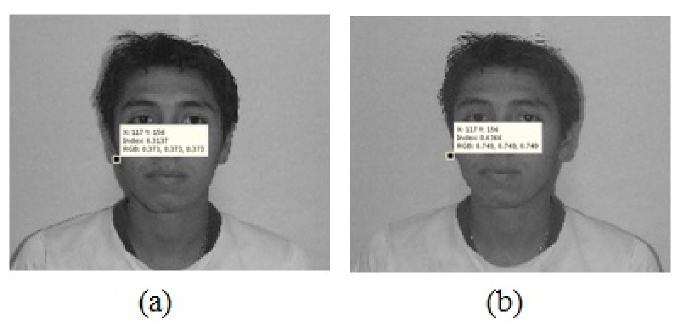

Fig. 4 Comparison of two points with the same coordinates from an image obtained from a 3D real face. The difference between luminance and intensity are 0.3137 and 65, respectively.

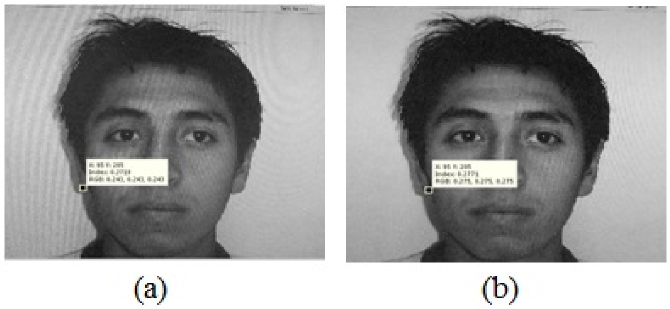

Fig. 5 Comparison of two points with the same coordinates from an image obtained from a 2D picture. The difference between luminance and intensity are 0.0065 and 2, respectively.

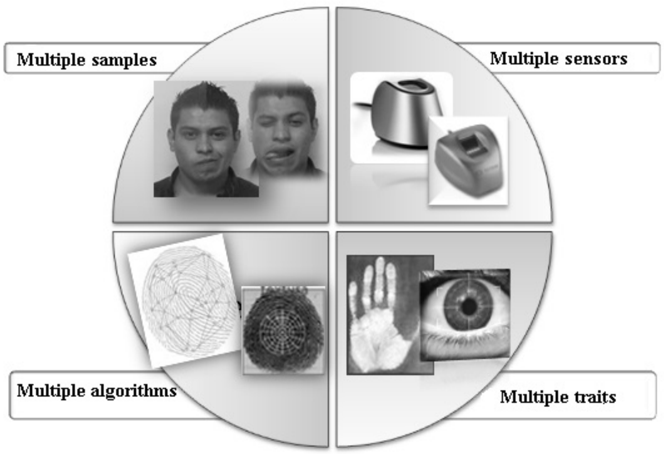

Fig. 6 Biometric characteristics that may be used by a Multi-biometric system

B. Multi-biometric systems

A system that consolidates the evidence obtained from multiple biometric sources is known as a multi-biometric system [12], [20]. Thus such systems, as shown in Fig. 6, use two or more biometric characteristics, sensors or algorithms, to overcome some of the limitations of the unimodal biometric systems. This is because the use of several biometric characteristics helps to increase the features space used to represent a person under analysis and reduce the effect of the distortion introduced in each individual feature during the acquisition process.

A multi-biometric system can be developed using several parameters levels of fusion, (Fig.6) some of them described in the next subsections.

C. Level of fusion

The fusion of information is a key part of a multi-biometric system, since the fusion of the different modules of the face recognition system can be done at distinct fusion levels such as sensor level, feature level and decision level. These fusion levels can also be broadly classified as: fusion prior to matching and fusion after matching [2], [18].

Sensor level fusion (Sensor-LF)

Sensor-level fusion, shown in Fig 7, refers to the combination of raw data obtained using multiple sensors or multiple snapshots of a biometric characteristics using a single sensor. For a face recognition system, the sensor level fusion consist of the fusion of left and right images of a 3D face that together form the stereo image, as is shown in figure 1. Here the input images are preprocessed, before being introduced to the system, firstly to determine if the images corresponds to a 3D face or a 2D picture. If the input images corresponds to a 3D face, the system proceeds to find the middle point in each image, cutting the half part of each image, the left part of the left image and the right part of the right image, where more significant information is taken, considering that the left half part of the left image is complementary to the right half part of the right image. Finally the resulting image is feed to the feature extraction stage of face recognition system to proceed with the identification or verification task.

Feature level fusion (Feature-LF)

Feature level fusion is the consolidation of the evidence presented by two biometric features sets of the same individual, when both feature sets are originated from the same feature extraction algorithm. Thus the feature level fusion can be used for template update. Thus the template in the database can be updated based on the evidence presented by the current feature set in order to reflect permanent changes in a person's biometric characteristics.

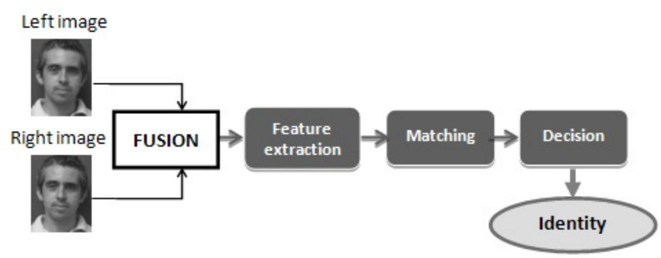

Fig. 7 Block diagram of sensor-LF

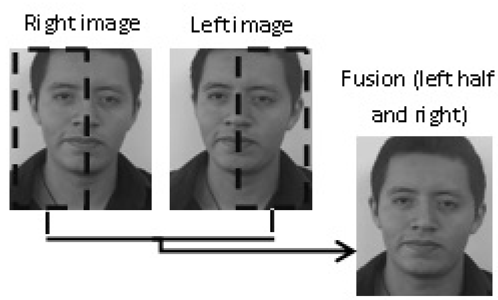

Fig. 8 Fusion image

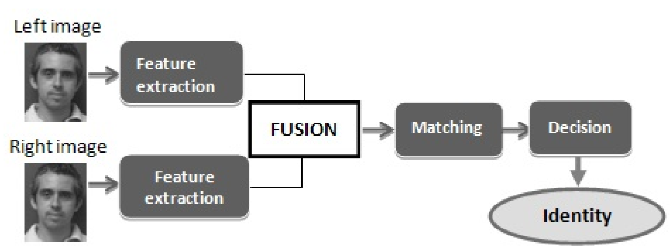

Fig. 9 Block diagram of feature-LF

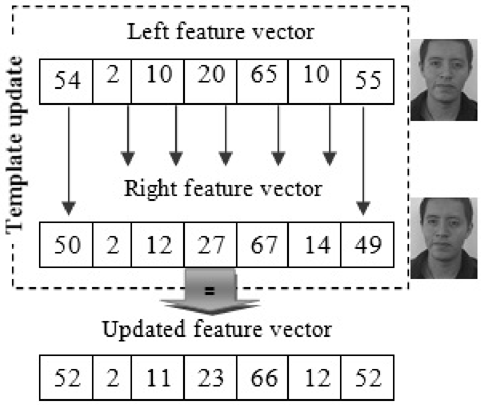

Fig. 10 Arithmetic mean features vectors

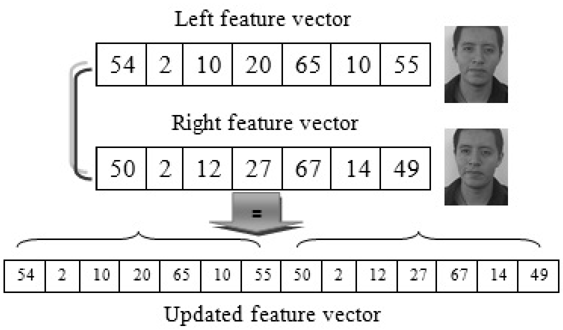

Figure 11 Concatenation of characteristic vectors

Several efficient feature extraction methods have been proposed during the last several years, among the Gabor Filters [7], [15] and Eigenfaces methods [3], [7] are some of the widely used methods used to extract the most relevant information from a facial image, allowing handling only the main parameters that make up each face. Thus once the feature vector of each face is obtained, it is introduced to the matching module using, either, a Back-propagation Neural Network or a Support Vector Machine, to identify the input image. This procedure is carried out only when there is information of a single source. Therefore, it can be consider that this process must be carried out twice, since this system has two separate images with different angles for each face. But within this level of fusion only one process is carried out for both images, adding a pre-processing stage before the input feature vector is feed to the matching module, as shown in fig. 9. The pre-processing task can be carried out using two different methods: the first one calculates the arithmetic mean of both vectors and the second one concatenates both feature vectors, giving as a result a single vector that is used to characterize the input face. This new template is then feed to the matching module.

The first method used for the fusion of features, consists on calculating the arithmetic mean between the features vector, corresponding to each stereo face image. Thus the n-th component of the resulting feature vector, is the average of n-th component the feature vector of left image of face with the n-th component of the right image feature vector, see Fig.10. After this new feature vector is obtained, it is feed into the matching stage to perform the identification or verification task as shown in fig. 9

The feature vectors obtained for each face image have the same length size, in this particular case of 70 values. Thus applying the second method for this level of fusion, which consist on the concatenation of the feature vectors corresponding to both stereo image of the 3D face, left and right parts, we obtain the union of all the values contained in both vectors, yielding to a resultant feature vector with twice length, that is 140 values, see Fig. 11. Next the resulting vector is used as the template for performing the identification or verification task as shown in figure 9.

Decision level fusion (Decision-LF)

This fusion operates in the decision stage, where every unimodal system provides an individual result regarding acceptation or rejection of a person asking for access to the global system, or an identification score regarding the potential identity of the person under analysis. These individual answers processed by a supervision stage, which takes a global decision using the individual score of each stage. The simplest method of combining the decisions outputs provided by different matchers is to use the "AND" logic operation or the "MAX". In the first case, which is the rule used for in this system for verification task, the output is true only when the output of all biometric matchers is true, while for identification the most used methods takes the maximum among all individual matchers.

In the decision fusion level the features of each facial image are extracted and the recognition process is performed, separately in each branch. Next the individual decision of each stage is feed it into a decision stage to make the fusion data comparing the results of each image. This process is shown in Fig 12.

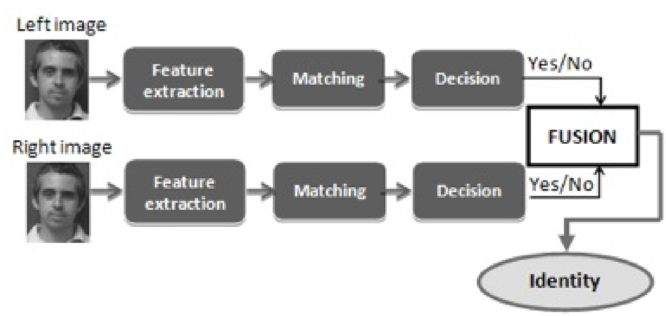

Fig. 12 Block diagram of decision-LF

III. Features extraction algorithms

Several efficient feature extraction algorithms have been proposed during the last several years, among them the eigenfaces and Gabor filter based feature extraction methods are some of the most widely used.

A. Eigenfaces

The PCA (Principal Components Analysis) is a widely used method for data dimensionality reduction and also has been used in the computer vision area, such as face recognition and object recognition. When the PCA is used in face recognition problems, the resulting algorithm is the so called Eigenfaces [3], [7]. Using this method the recognition is performed by projecting a new image into the subspace spanned by the Eigenface (face space) and then classifying the face by comparing its position in the face space with the positions of known individuals. Each individual, therefore, would be characterized by the small set of feature weights needed to describe and reconstruct them. This is an extremely compact representation when compared with the images themselves [3].

This method involves the following operations: Firstly, assuming that the width and height of the image under analysis are n and m pixels, respectively, the image is transformed into a vector of size $d=n*m$. Next given M pre-processed facial images, the training data are converted into the corresponding M column vectors $I=\{I_n(x,y),\ n=1,2,\ldots,M\}$. The average of these training set is estimated as

$$\Psi=\frac{1}{M}\sum_{n=1}^{M} l_n \tag{1}$$

Next the mean-adjusted image is be defined as

$$\Phi = l_n - \Psi,\ \ \textit{for n=1,2,...M} \tag{2}$$

Let C denote the covariance matrix and be defined as

$$C=\frac{1}{M}\sum_{n=1}^{M}\Phi_n\Phi_n^T=\frac{1}{M}AA^T \tag{3}$$

where $A=\left[\Psi_1,\Psi_{2,...,}\Psi_M\right]$

The principal components are then the eigenvectors of C, where C is a $d*d$ matrix. Thus it can be decomposed in d eigenvectors $V_1, V_2, \ldots, V_d$ and d eigenvalues $\lambda_1,\lambda_2,\ldots,\lambda_d$. However, it is time-consuming to determine d eigenvalues and eigenvectors. Therefore, it is necessary to reduce the computation complexity. According to SVD (Singular Value Decomposition), AA^T and A^TA have the same eigenvalue λ_d. As a result, instead of directly computing eigenvectors u_i of matrix AA^T, eigenvectors v_i of matrix A^TA are computed. Thus the eigenvectors u_i of matrix AA^T can be defined by

$$u_i=\frac{1}{\sqrt{\lambda_i}}Av_i \tag{4}$$

These eigenvectors are used to characterize the input images.

B. Gabor filters

The Gabor functions, keep a strong relation with the human visual system that make them suitable for face recognition applications. The Gabor functions are determined by four parameters, the spatial location (x,y) the frequency (F) the relation between x and y (λ) and the orientation (ϕ) [3], [7], [8]. The Gabor functions are given by

$$h_c(x,y)=g(x',y')\cos(2\pi Fx') \tag{5}$$

$$h_s(x,y)=g(x',y')sen(2\pi Fx') \tag{6}$$

Where

$$g(x',y')=\left(\frac{1}{2\pi\lambda\sigma^2}\right)\exp\left[-\frac{(x/\lambda)^2+y^2}{2\sigma^2}\right] \tag{7}$$

and

$$(x',y')=(x\cos\phi+ysen\phi,-xsen\phi+y\cos\phi) \tag{8}$$

Where x' and y' are the rotated coefficients of x and y.

An efficient method for estimating a suitable feature vector was proposed by [7], where the image under analysis is divided in NxM sub-blocks which are correlated with L different Gaussian functions, obtained from (5) to (8) using R angles, q=1,2,..,Q, and R frequencies where r=1,2,4,..,R and L=QR. Next using the first element of the cross correlation between the *c-th* sub-block and the *(q,r)-th* Gaussian function the total energy contrast for each block is estimated which is given by

$$M_c=\frac{\sum_{q=1}^{Q}\sum_{r=1}^{R}M_{r,q}(x,y)}{RQ} \tag{9}$$

Where

$$M_{r,q}(x,y)=\sqrt{\rho_c^2+\rho_s^2} \tag{10}$$

Denotes the magnitude between for the first point of the cross-correlation between the *(r,q)-th* Gaussian function and the *c-th* sub-block. A detailed description of this feature extraction method can be obtained in [7] and [8].

IV. Classification

Several efficient classification algorithms have bee proposed during the last several decades which are an essential part of any pattern recognition algorithms, whose goal is to learn the main characteristics of the patterns under analysis, during the learning phase and generalize this knowledge to take the best decision during the recognition stage.

Attending to their learning mechanisms, the classification schemes can be divided in Supervised, unsupervised, semi-supervised and transduction. Here the supervised learning minimizes a criterion between the inputs and the desired outputs of the system. The unsupervised learning models a set of inputs, such as a clustering minimizing a given criterion without using a desired output. The semi semi-supervised learning combines both labeled and unlabeled examples to generate an appropriate function or classifier; and finally the transduction tries to predict new outputs on specific and fixed (test) cases from observed, specific (training) cases. Among all of them, when a desired respond is available, the supervised are more widely used because they achieve a lower error and require less training time. Two widely used supervised schemes are the neural network and the support vector machine which are briefly described in the next subsections.

A. Neural network back propagation

The back-propagation neural network is a generalization of the least mean squares algorithm. This algorithm is a multilayer network which performs the task of updating weights and profits based on the mean square error. The back-propagation network works under supervised learning, where the set value of the weights is based on the generated error. This technique is widely used because it allows an optimization method which is to define the gradient of the error and minimize it with respect to the parameters of the neural network [11].

This network learns a predefined set of inputs and outputs dice, using a spread-cycle two-stage adaptation. Once you have applied an input pattern as a stimulus to the first layer of the network units, this is spread through all the upper layers to generate an output. The output signal is then compared with the desired output, and is calculated an error signal for each output unit. Error signals are then transmitted backwards from the output layer to every node in the middle layer contributing directly to the output. However, the units of the intermediate layer only receive a fraction of the overall error signal, based on the relative contribution about who has contributed the original output unit. This process repeats, layer by layer, until all network nodes have received an error signal that describes its relative contribution to total error. Based on the perceived error signal, updates the connection weights of each unit to make the network converge to a state that allows encode all trained frames. The importance of this process is that, as the network is trained, the nodes of the intermediate layers themselves are organized so that the different nodes learn to recognize different features of the total space of inputs.

An important feature of this algorithm is the internal representation of the knowledge that is able to arrange in the intermediate layer of neurons to achieve any correspondence between input and output of the network. The learning algorithm using back-propagation consists of: Firstly start with any synaptic weights (usually random). Next enter an input layer randomly chosen from the input data to be used for training. Subsequently let the network generates an output data vector (forward propagation). Then compare the output generated by the network with the desired output. Next the obtained difference between the generated and desired output (called error) is used to adjust the synaptic weights of the neurons of the output layer. Then the error is back-propagated (back-propagation) to the previous neurons layer to be used for adjusting the synaptic weights in this layer. The back-propagating error and adjusting the weights continues until it reaches the input layer. This process is repeated with different training data.

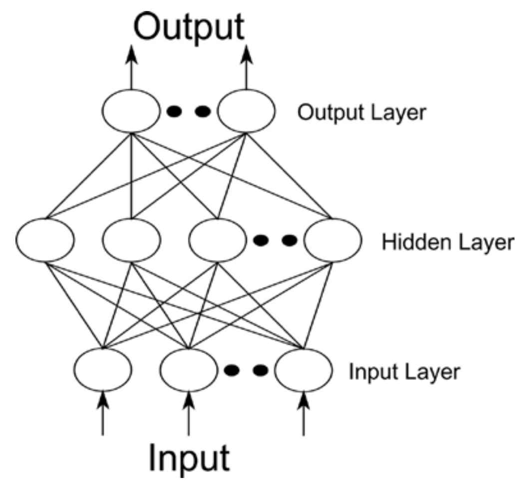

Fig. 13 Back-propagation neural network

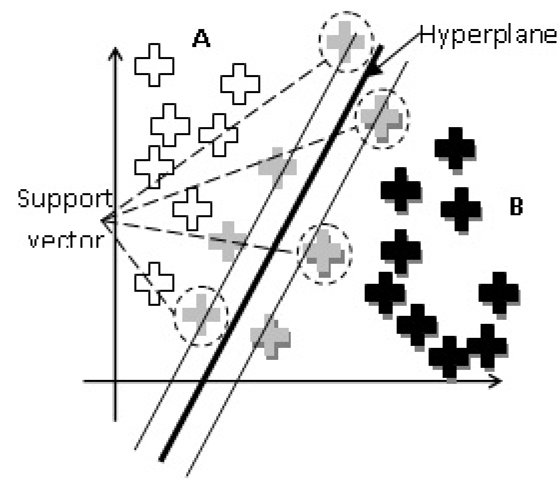

Fig. 14 Support Vector Machine

B. Support Vector Machine (SVM)

The SVM is a supervised pattern recognition method used for classification and regression. It learns the decision surface of two different classes of entry points. As a classifier of one class, the description given by the details of the support vectors is able to form a decision boundary around the domain of the training data with little or no knowledge of the data out of that border. The data are mapped by means of a Gaussian kernel or other type of Kernel to a feature in an area higher dimensional, where it's seeks the maximum separation between classes. This border function, when brought back to the input space, can separate the data in all different kinds, each forming a cluster [13], [19].

A set of features that describes one case is called a vector and goal of SVM modeling is to find the optimal hyperplane that separates the cluster vectors, the vectors near the hyper plane are the support vectors, as shown in Fig. 14 SVM must deal with, more than two predictor variables, separating the points with non-linear curves, handling the cases where clusters cannot be completely separated, and handling classifications with more than two categories.

V. Evaluation Results

The evaluation of proposed face recognition system has divided into four stages. Firstly the performance of pre-recognition stage, which determines is the images under analysis corresponds to a real 3D face or corresponds to a 2D picture. Next the evaluation of proposed system using 3 different level of fusion is provided, when the proposed system is require to operate in either, identification or verification configurations. To obtain the evaluation results, the configuration shown in Fig. 15 is used. Firstly the pre-processing stage was evaluated to determine its performance when it is required to determine if the image corresponds or not to a real 3D image. To this end the evaluation system shown in Fig.16 was used. The pre-recognition stage is to prevent spoofing, i.e., in this process the captured image is evaluated to identify if what is being presented to the system is a real or fake face. Evaluation results using 50 images, 35 from authentic 3D faces and 15 from 2D pictures show that the system is able to discard in all cases the images taken from 2D pictures. Some typical examples are shown in table one, where the decision threshold was set equal to 1300 and 1750 for the intensity and luminance respectively.

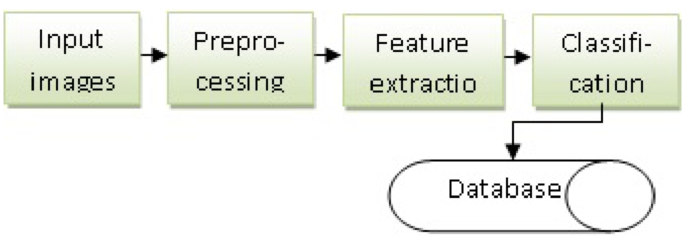

Fig. 15 Training configuration

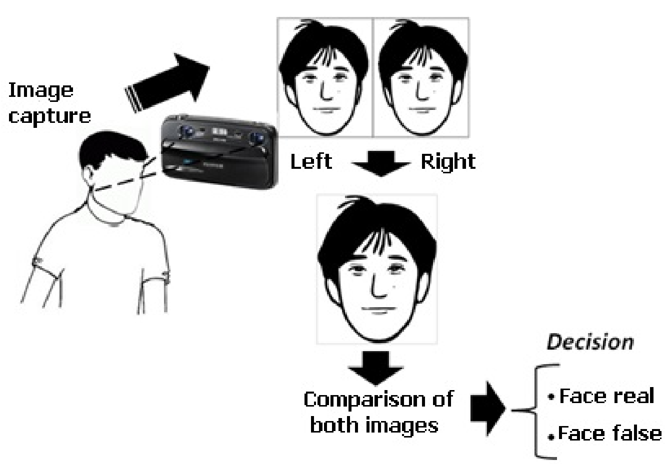

Fig. 16 Pre-recognition stage

TABLE I Comparison of data obtained in Luminance and Intensity to 5 pictures true and five false images.

Image	Luminance threshold	Intensity Threshold	Status
Image of a real face 1	3643	2924	True
Image of a real face 2	6479	5678	True
Image of a real face 3	4496	3665	True
Image of a real face 4	2011	1309	True
Image of a real face 5	4241	2690	True
Image of a false face 1	270	129	False
Image of a false face 2	208	57	False
Image of a false face 3	576	300	False
Image of a false face 4	246	160	False
Image of a false face 5	714	541	False

TABLE II Images Database

For testing of the fusion level stereo images of faces, captured with a digital camera containing two lenses were used. Table II show a set of such images. The capture images are in a controlled environment, since they were taken with a solid-colored background, with the same distance between the face and the camera, the same type of lighting, without rotation and are taken with a little variation of gestures. The images taken were from 60 different people, with 15 images per person and considering that for every capture of image is a pair of images extracted, giving a total of 1800 images of faces.

In the matching module was used the Neural Network of Back-propagation and Support Vector Machine with 1200 images in total for the learning, taking the rest of the images for the tests of identification and verification of faces. Thus, evaluating the behavior of the recognition system in each of the levels of fusion were obtained different percentages of identification and verification, by making a selection of the level of fusion with the best performance of face recognition.

TABLE II Percentages of identification

Levels of Fusion		*Neural Network Back-propagation*		*Support Vector Machine*	
		Eigenfaces	**Gabor**	**Eigenfaces**	**Gabor**
Sensor level fusion		96,22%	95%	99,22%	99,50%
Feature level fusion	Arithmetic mean	96,66%	97,88%	99,59%	99,76%
	Concatenation	91,77%	94,66%	99,78%	99,82%
Decision level fusion		91,55%	93,77%	99,40%	99,50%
Only right part		94,77%	94,33%	99,46%	99,51%
Only left part		94,33%	93,77%	99,50%	99,52%

TABLE III Percentages of verification with the Neural Network Back-propagation

Levels of Fusion		*Eigenfaces*			*Gabor*		
		% FAR	**% FRR**	**% Verification**	**% FAR**	**% FRR**	**% Verification**
Sensor level fusion		0,23%	0%	99,78%	0,23 %	0%	99,77%
Feature level fusion	Arithmetic mean	1,24%	0%	98,75%	0%	0%	100%
	Concatenaion	0%	0%	100%	0,68 %	0%	99,32%
Decision level fusion		0,68%	0%	99,32%	0,23 %	0%	99,77%

TABLE IV Percentages of verification with the Support Vector Machine

		Eigenfaces			***Gabor***		
Levels of Fusion		**% FAR**	**% FRR**	**% Verification**	**% FAR**	**% FRR**	**% Verification**
Sensor level fusion		0,11%	0%	99,88%	0,11%	0%	99,88%
Feature level fusion	Arithmetic mean	0,11%	0%	99,88%	0%	0%	100%
	Concatenatio n	0%	0%	100%	0%	0%	100%
Decision level fusion		0,11%	0%	99,88%	0,11%	0%	99,88%

IX. Conclusion

This paper proposes a face recognition system using of the fusion of different levels with stereo images of the face, also made the comparison of the behavior of the system using two extraction methods features combining with two types of classifiers. The purpose of using different levels of fusion is make a multi-biometric system making it more robust since these fusion levels evaluate more information from more than one characteristic of the face and provide a better identification of the person. The three levels of fusion that were evaluated, in general, all show good identification performance, however, the behavior of each is different. The method with best performing is feature level fusion, because at joining the main features of the face is shown that the greater the number of features obtained more likely identify a person and lower the likely that system is susceptible to forms of cheating.

The other part that is being worked in the pre-recognition stage for know if it's a face real or face false, this in order to detect from the input to the system if it is a sup plantation of identity. That among the tests performed was able to deduce that with the help of stereo images, you can calculate the depth of the face and thus determine if it's a real face.

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