Efficient Technique for Facial Image Recognition with Support Vector Machines in 2D Images with Cross-Validation in Matlab

JOSE AUGUSTO CADENA MOREANO
Facultad de Ingeniería de Sistemas e Informática
Universidad Nacional Mayor “San Marcos”
Av. Universitaria
Lima, PERU

NORA BERTHA LA SERNA PALOMINO
Facultad de Ingeniería de Sistemas e Informática
Universidad Nacional Mayor “San Marcos”
Av. Universitaria
Lima, PERU

Abstract: - This article presented in the context of 2D global facial recognition, using Gabor Wavelet's feature extraction algorithms, and facial recognition Support Vector Machines (SVM), the latter incorporating the kernel functions: linear, cubic and Gaussian. The models generated by these kernels were validated by the cross validation technique through the Matlab application. The objective is to observe the results of facial recognition in each case. An efficient technique is proposed that includes the mentioned algorithms for a database of 2D images. The technique has been processed in its training and testing phases, for the facial image databases FERET [1] and MUCT [2], and the models generated by the technique allowed to perform the tests, whose results achieved a facial recognition of individuals over 96%.

Key-Words: Facial recognition, support vector machines, gabor wavelet, kernels, 2D images, databases feret, databases muct.

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1 Introduction

Face recognition has now become an area of active research that encompasses various disciplines, such as image processing, pattern sorter, computer vision, etc. This research topic has been around for many years, but it is always in permanent progress until at some point you can reach 100% recognition, also within the field of object recognition, where the face is a three-dimensional subject to variations of lighting, gestures, pose, etc. It is important to consider the difference between identification and verification. The identification is when the system at the exit determines the identity of the person with the highest approximation among a set of known people (stored in a database) and the verification is when the system determines if the person is whom they say they are [3]. For this recognition work, the Support Vector Machines (SVM) algorithm was considered because it is very efficient in the subject of classification, the same one that is used more than the subject of images in other areas such as: Traffic accidents [4], Financial modeling [5], classification of texts [6], prediction of maximum particle velocity [7], classification of energy quality [8], identification of seismic patterns [9], and other. Likewise, the recognition process requires a decrease in the number of entries and its density in the SVM, for which the Gabor filter in Matlab [10], [11], [12], [13] was used. The investigation is structured on the basis of sections, the same one that is focused on Gabor's wavelet state of the art and the support vector machine (SVM), very important algorithms for the process of extraction of characteristics and classification of patterns respectively. Below is a description of the technique used with Gabor and SVM in the face recognition process, a description of the experiments carried out with the software designed for it is also made, then an analysis of the results obtained is carried out, both in the training and in the testing stage. In function of citizen security, the control of the entry and exit of personnel, etc., it is necessary to advance in search of an increasingly efficient algorithm in the facial recognition process, which is further justified in this work. Finally, the respective conclusions and future works are established.

2 Literature Review

2.1 Vectors Support Machines (SVM)

Facial or facial recognition is a biometric method that has a large field of application in the technological world today, especially in regard to security. Thus, it could be used on a smaller scale in access systems for companies, universities, recognition of friends in social networks, identification in a cell phone, computer or Tablet, access to ATMs, etc.

According to Cabello [14] the SVM are techniques considered as cl assifiers, considering that a classifier is an algorithm that allows defining a model for each class, in such a way that the class to which an element belongs can be calculated from the values of the data that define the element. On the other hand, Betancourt [15] states that the theory of Vector Support Machines (SVM by its English name Support Vector Machines) is a new classification technique.

Realizing a bit of history, the theory of the SVM was developed by Vladimir Vapnik [16] by the 90s, appears in works on the theory of statistical learning.
This technique contemplates 2 phases: A first of training and another of decision or test. In this first phase, the main objective is to find a decision function, capable of separating the two classes. In the case that the classes are not easily separable, then the training vectors are projected to a higher dimension space by means of non-linear transformation functions, which can be a k ernel function that allows adapting the distribution of patterns to be able to separate the same without any difficulty.

The SVM technique is illustrated in Figure 1, as follows:

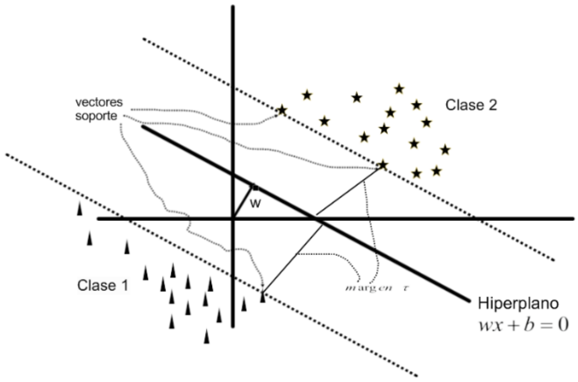

Fig. 1. A graphic diagram of a support vector machine

Support Vector Machines have characteristics that have put them at an advantage over other popular classification and/or regression techniques, one of which is that they belong to the disciplines of automatic learning or statistical learning. The idea behind this type of learning is to make the machines can learn, through examples. The SVM algorithm is developed based on important Kernel functions such as Linear, cubic, Gaussian, radial base function (RBF), etc. According to Nayef [12], the application of wavelet transformation is the first stage of the facial recognition system. The wavelet transform plays two important functions: The first one decomposes the resolution of the face thus reducing the number of entries to the SVM. The second function is to eliminate the density in everything except the lower subband.
An image is decomposed once into four secondary bands (LL, LH, HL, HH) as shown in Figure 2. The LL band is a thicker approximation to the original image. In the LH and HL bands respectively, the changes of the image are recorded along the horizontal and vertical directions, while the HH band shows a higher frequency component of the image. Example, if the 112x92 image decomposed once the size of the subbands 1, 2, 3, 4 becomes 56x64. Therefore, the size of the input image is broken down in half.

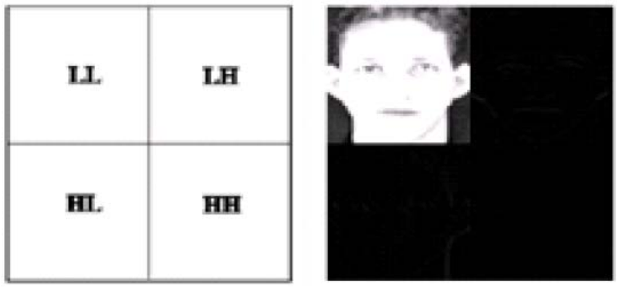

Fig. 2. Images of faces with wavelet transform of a level [12]

2.2 Technical with Wavelet de Gabor and Support Vector Machine

Figure 3 s hows a scheme of the technique developed for global recognition of 2D facial images, which includes the training and test phases, in both cases, 2D facial image databases are required. At the same time, the technique contains the algorithm for the extraction of characteristics of GABOR [10], [11], [12], [13] that in Matlab corresponds to two functions, the first function called "gaborFilterBank.m" that generates a bank of Gabor filters of customized size, the same one that creates an array of cells, whose elements are **m** by **n** matrices; each matrix is a Gabor 2-D filter. The second function called "Gabor features.m" that extracts the Gabor characteristics of an input image. Create a column vector, which consists of the Gabor characteristics of the input image (characteristic vectors). And finally, there is the algorithm for facial recognition support vector machine. In this last algorithm, three kernels are incorporated: linear, cubic and Gaussian. The objective is that the proposed technique can be processed with each of the kernels described in the two databases FERET

[1] and MUCT [2], and observe their results in each case.

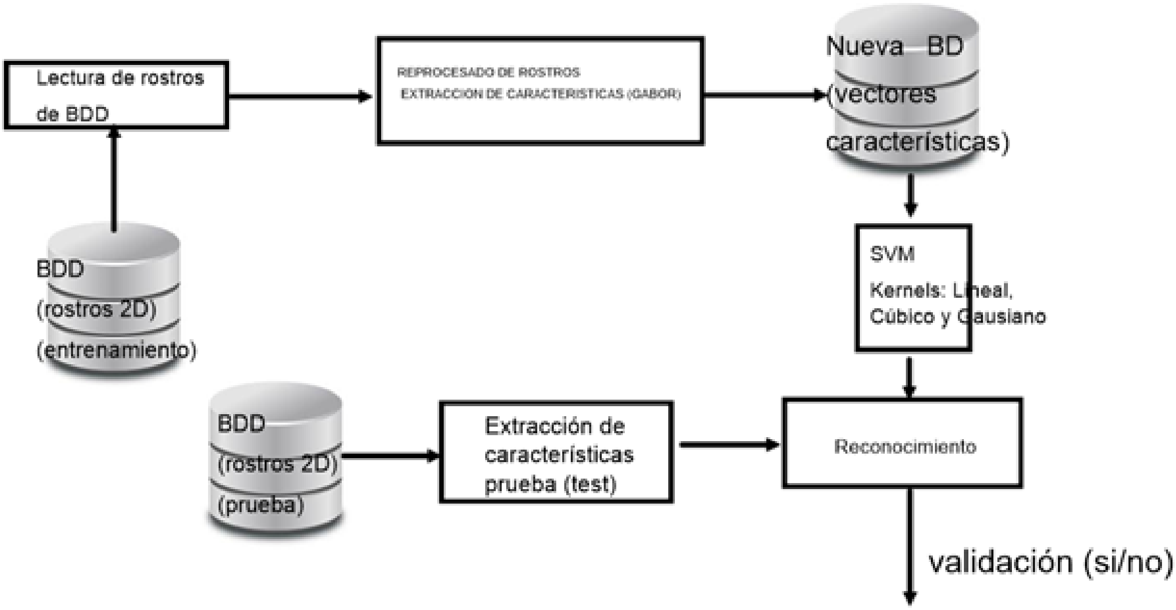

Fig. 3. The technique proposed with wavelets and support vector machine.

In the training phase, the Gabor algorithm, for the extraction of characteristics, has as input 2D facial images, and as o utput the set of feature vectors of the considered database. These characteristic vectors were created by the gaborFeatures.my function and are located in a filter bank created by gaborFilterBank.m, while the SVM algorithm has as input the set of characteristics of the images and as outputs three models for facial recognition, which correspond to the processing of each of the kernels considered in the SVM algorithm. Figure 4 shows the interface of the training phase.

Fig. 4. The interface of the software training phase.

In the test phase, we have as input a database of 2D facial images, where the individuals considered are different to the training phase. For each facial image of the test entry database, the Gabor algorithm is applied, and the facial features (characteristic vectors) of the image are extracted, and the recognition process is executed, resulting in the validation of the individual is in the training database, or does not validate it, if the individual is not in that database.

In the last process, a pairing of the test image occurs with some individual that is in the training database, then the test image is validated, otherwise if no pairing is not validated. A software was developed to implement the technique, the system was developed with MatLab version R2015a and the training and testing phases were run using databases of selected 2D images, in an HP Corel I5 computer, which are described in the next section.

2.3 Cross Validation

The cross-validation topic according to [17], is a statistical method used to estimate the ability of machine learning models. This technique is commonly used in machine learning applied to compare and select a m odel, this cross-validation divides the training data into several disjointed parts of the same size.

Cross validation has many applications, such as method validation in laboratories [18], in speed measurement models [19], in validating control strategy models [20], etc.

3 Problem Solution

To validate the developed technique, experiments were carried out, for which two databases of 2D facial images were selected: FERET [1] and MUCT [2]. For the experiments, two databases of 2D facial images have been selected: FERET [1] and MUCT [2]. Table 1 shows the characteristics of the 2D facial images of the bases that have been used in the training and testing phases, using the developed technique.

Table 1. Characteristics of databases FERET [1] and MUCT [2] for experiments

Databases used	Pixeles	Training # Images /# Individuals/# images per individual	Tests # Images /# Individuals/ # images per individual
FERET [1]	480 x 640	100/20/5	100/20/5
MUCT [2]	480 x 640	1212/101/12	300/25/12

The FERET database (Face Recognition Technology) [1], managed by the DARPA Agency (Defense Advanced Research Projects Agency), and NIST (National Institute of Standards and Technology), the images include variations in pose, expressions and different types of illumination.

The MUCT database [2], consists of 2D facial images that show diversity in lighting, age, and race.

Figure 5 shows examples of images from the FERET database [1] used in the experiments.

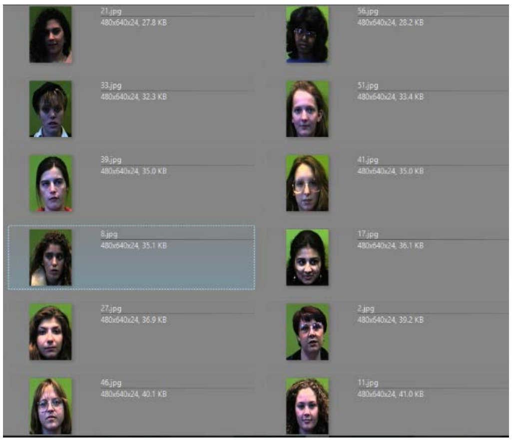

Fig. 5. Examples of images from the FERET database [1].

Figure 6 shows examples of images from the MUCT database used in the experiments to validate the proposed technique.

Fig. 6. Examples of images from the MUCT database [2].

The experiments with the FERET database were carried out in the two phases: training and testing. In both phases, 100 images of 20 individuals were processed, and 5 images per individual. The experiments with the MUCT Database are carried out in the two phases: training and testing.

In the training phase, 1212 i mages of 101 individuals, 12 i mages per individual, were processed. In the test phase, 300 images of 25 individuals, 12 i mages per individual, were processed.

Feature extraction performs some transformation of the original features to generate other features that are more meaningful [22]. So far the most common way to analyze the periodic properties of the textures is performed by processing by a bank of special filters called Gabor filters. These are roughly bandpass filters, which give information on the spatial frequencies containing the images, and their orientation. Each of the spectra of the Gabor filter according to Mariñas [23], defined by three parameters:

1) The center frequency, which highlighted if the texture has significant spatial frequency components to that.
2) Scaling, which will pass more or less frequencies around the center frequency.
3) Orientation, in view that in the domain of images (two-dimensional) frequencies defined as vectors with magnitude and phase. This phase or orientation distinguish, for example horizontal stripes of the vertical, to the same frequency.

The technique developed for each of the selected databases was applied, in the training phase, the Gabor algorithm was first applied for the extraction of characteristics, generating a set of characteristics of the selected images, and then applied for each kernel (linear, cubic and Gaussian) the SVM algorithm, generating a facial recognition model for each of the mentioned kernels.

For validation of the model, cross validation was applied, which consists of an evaluation technique used to evaluate the performance of a machine learning algorithm. This technique consists of dividing the trained data set into N subsets, each subset is validated or tested with each of the remaining ones, that is, N-1 subsets, obtaining a validation error for each process, the final result will be the average of all errors, which represents the average validation error. This process is indicated in table 2.

Table 2. Cross Validation Process

Subset_1	PARTITION OF TRAINING DATA SET IN 10 SUB-SETS
Subset_2	
Subset_3	
Subset_4	
Subset_5	
Subset_6	
Subset_7	
Subset_8	
Subset_9	
Subset_10	

	VALIDATION_2_1	VALIDATION_3_1	VALIDATION_4_1	VALIDATION_5_1
VALIDATION_1_2		VALIDATION_3_2	VALIDATION_4_2	VALIDATION_5_2
VALIDATION_1_3	VALIDATION_2_3		VALIDATION_4_3	VALIDATION_5_3
VALIDATION_1_4	VALIDATION_2_4	VALIDATION_3_4		VALIDATION_5_4
VALIDATION_1_5	VALIDATION_2_5	VALIDATION_3_5	VALIDATION_4_5	
VALIDATION_1_6	VALIDATION_2_6	VALIDATION_3_6	VALIDATION_4_6	VALIDATION_5_6
VALIDATION_1_7	VALIDATION_2_7	VALIDATION_3_7	VALIDATION_4_7	VALIDATION_5_7
VALIDATION_1_8	VALIDATION_2_8	VALIDATION_3_8	VALIDATION_4_8	VALIDATION_5_8
VALIDATION_1_9	VALIDATION_2_9	VALIDATION_3_9	VALIDATION_4_9	VALIDATION_5_9
VALIDATION_1_10	VALIDATION_2_10	VALIDATION_3_10	VALIDATION_4_10	VALIDATION_5_10

VALITACION_6_1	VALITACION_7_1	VALIDATION_8_1	VALIDATION_9_1	VALIDATION_10_1
VALITACION_6_2	VALITACION_7_2	VALIDATION_8_2	VALIDATION_9_2	VALIDATION_10_2
VALITACION_6_3	VALITACION_7_3	VALIDATION_8_3	VALIDATION_9_3	VALIDATION_10_3
VALITACION_6_4	VALITACION_7_4	VALIDATION_8_4	VALIDATION_9_4	VALIDATION_10_4
VALITACION_6_5	VALITACION_7_5	VALIDATION_8_5	VALIDATION_9_5	VALIDATION_10_5
	VALITACION_7_6	VALIDATION_8_6	VALIDATION_9_6	VALIDATION_10_6
VALIDATION_6_7		VALIDATION_8_7	VALIDATION_9_7	VALIDATION_10_7
VALIDATION_6_8	VALIDATION_7_8		VALIDATION_9_8	VALIDATION_10_8
VALIDATION_6_9	VALIDATION_7_9	VALIDATION_8_9		VALIDATION_10_9
VALIDATION_6_10	VALIDATION_7_10	VALIDATION_8_10	VALIDATION_9_10	

In the test phase, the images selected for the test process were considered, and for each image, the Gabor algorithm was applied, and from the vector of characteristics of the test image, the model of each SVM kernel obtained in the training phase of the corresponding database. The objective of applying SVM with each kernel is to observe the results in each case. The results and their discussion of applying the technology developed with the databases of 2D facial images are shown in the following section.

4 Results

4.1 Model Validation Results

As for the validation of the model, it is carried out by cross validation, part of the results obtained with the two databases and their respective kernels are indicated in the figures: 7, 8, 9, 10, 11 and 12.

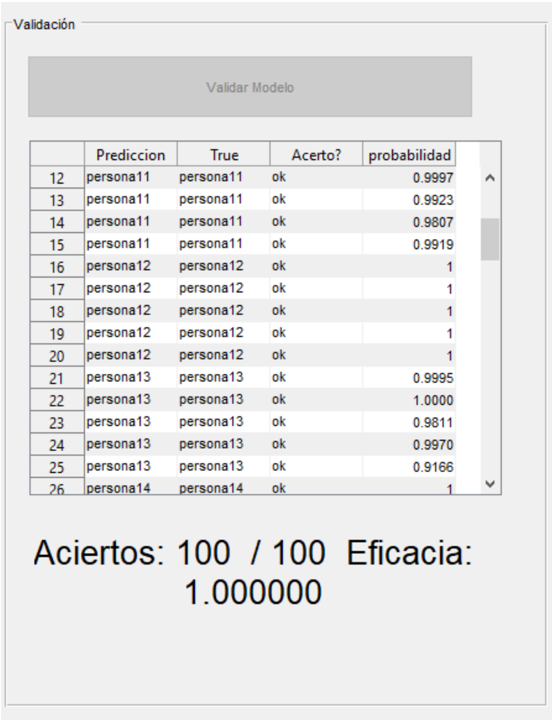

Fig. 7. Model validation, bdd Feret kernel linear

Jose Augusto Cadena Moreano,
Nora Bertha La Serna Palomino

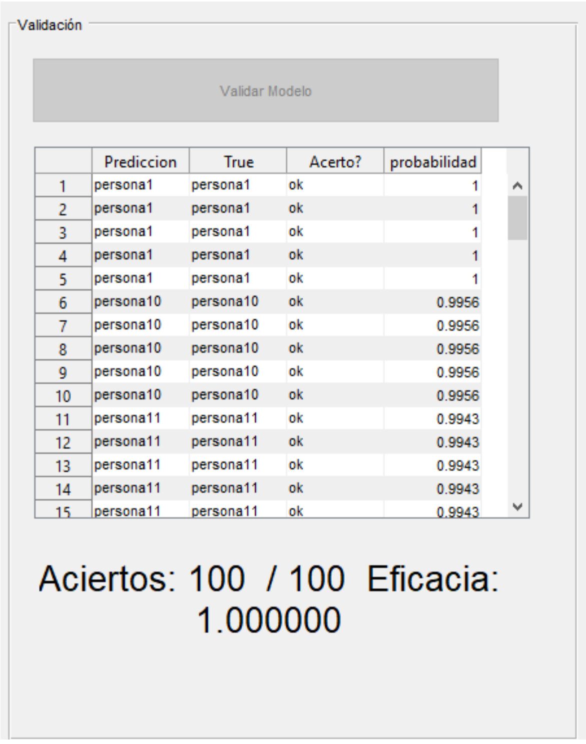

Fig. 8. Model validation, bdd Feret kernel Cubic

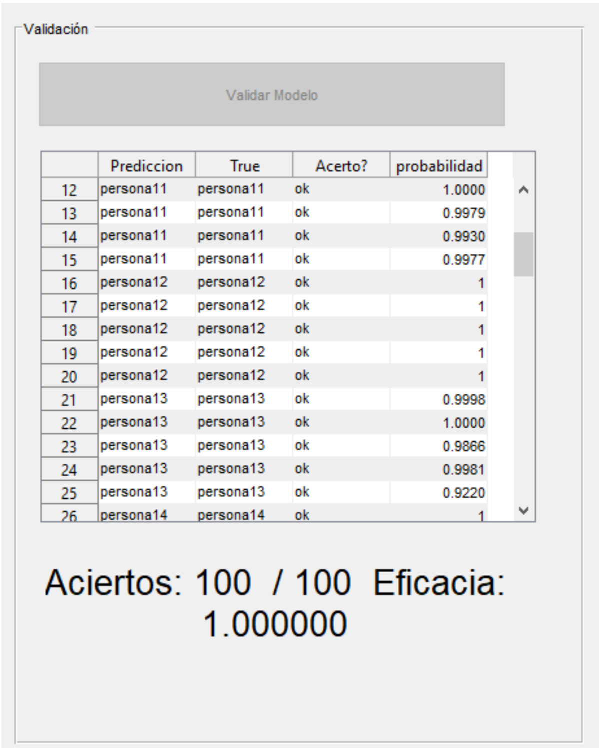

Fig. 9. Model validation, bdd Feret kernel Gaussian

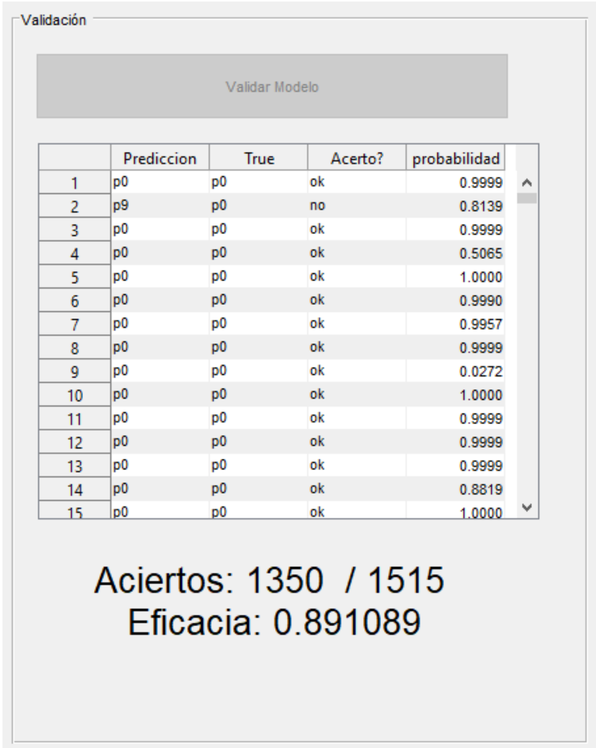

Fig. 10. Model validation, bdd Muct kernel linear

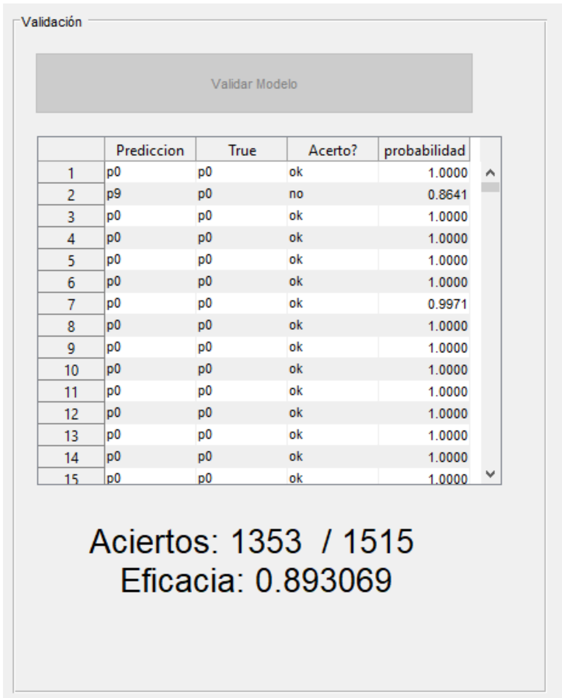

Fig. 11. Model validation, bdd Muct kernel Cubic

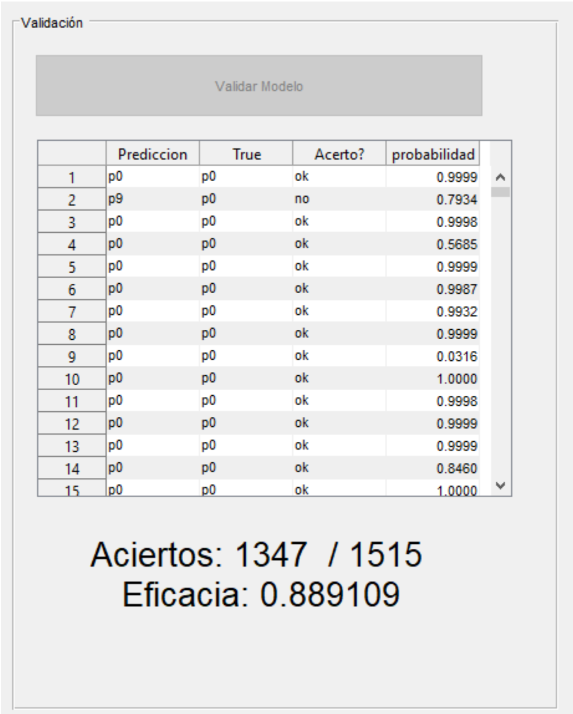

Fig. 12. Model validation, bdd Muct kernel Gaussian

The results obtained from the model validation are summarized in Table 3.

Table 3. Model validation summary

DATABASES	KERNEL LINEAR (%)	KERNEL CUBIC (%)	KERNEL GAUSSIAN (%)
FERET	100,0	100,0	100,0
MUCT	89,1	89,3	88,9

4.2 Results and Analysis with the FERET Database

When applying the technique presented in Section 3, and according to the experiments described in the previous section with the 2D FERET image database, the percentage of recognition with the kernel: Linear is 95%, with the Cubic is 92 %, while with the Gaussian 96%, for a total of 100 test images made with the developed technique, as presented in table 4.

Table 4. Distribution by a number of recognized FERET images for each kernel function

PERCENTAGE OF CLASS RECOGNITION ACCORDING TO APPLIED KERNEL - BDD FERET				
KERNELS	25 Images	50 Images	75 Images	100 Images
Kernel_Linear (%)	100,0	100,0	96,0	95,0
Kernel_Cubic (%)	92,0	92,0	90,7	92,0
Kernel_Gaussian (%)	100,0	100,0	96,0	96,0

Figure 13 shows graphically the results obtained from the experiments performed with the images, obtained in the test phase. In it, it is observed that the greater number of test images, the recognition percentage improves with each kernel.

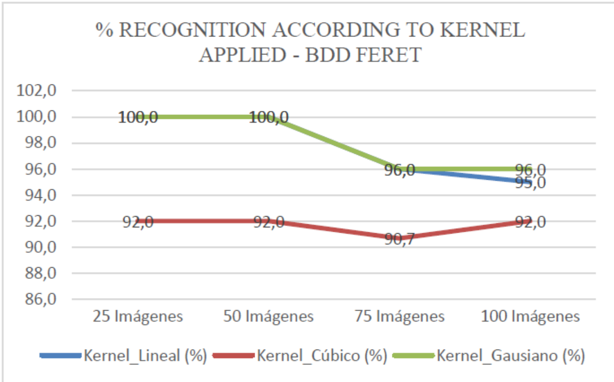

Fig. 13. Percentage of recognition with the kernel functions for the SVM with FERET.

4.3 Results and Analysis with the MUCT Database

In the case of the experiments performed with the MUCT database, the percentage of recognition with the kernel: linear is 89.4%, with the Cubic is 93.7%, while with the Gaussian it is 90.4%, see Table 5, for a total 303 test images made with the technique developed.

Table 5. Distribution by a quantity of MUCT images recognized for each kernel.

PERCENTAGE OF CLASS RECOGNITION ACCORDING TO APPLIED KERNEL - BDD MUCT						
KERNELS	50 Images	100 Images	150 Images	200 Images	250 Images	303 Images
Kernel_Linear (%)	100,0	98,0	93,3	91,0	90,4	89,4
Kernel_Cubic (%)	100,0	95,0	94,0	94,0	93,2	93,7
Kernel_Gaussian (%)	100,0	99,0	94,0	92,5	91,6	90,4

Figure 14 shows graphically the results obtained from the experiments performed with the images of the test phase of the technique. It is observed in this case that the greater the number of test images, the lower the recognition percentage with each kernel.

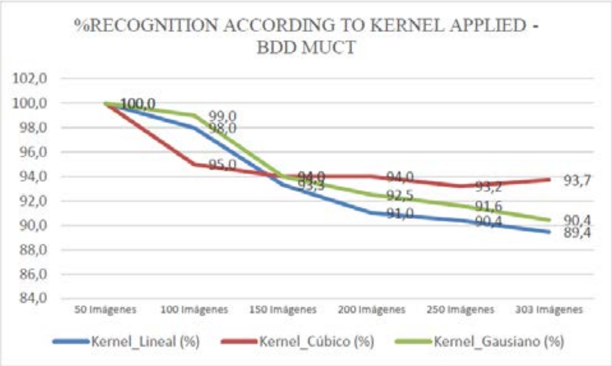

Fig. 14. Percentage of recognition with the SVM kernels with MUCT.

Additionally, other experiments that work with the methods of [21]: Local phase quantization (LPQ), Down Sampling (DS), The Local Binary Patterns (LBP) and Gabor, all combined with SVM, were reviewed.

The results obtained in our experiment were compared with those related to the topic of 2D facial recognition, a summary is indicated in table 6.

Table 6. Comparison with other related works

Methods	Databases	Rate of recognition
LBP+SVM [21]	RAFD-FRONT	86,50%
Gabor+SVM [21]	RAFD-FRONT	83,10%
LPQ+SVM [21]	RAFD-FRONT	84,80%
DS+SVM [21]	RAFD-FRONT	79,00%
ours proposed	FERET	96,00%
ours proposed	MUCT	93,70%

In the comparisons made, it is visible that our method that consists in projecting the face of a model of the FERET and MUCT database, then filtering and extracting characteristics to finally perform the classification has been very solid with respect to the works reviewed.

4 Conclusions

In this research, we have worked with databases of two dimensions (2D), such as FERET and MUCT. Likewise, from the review of the literature, the most efficient algorithms were analyzed, concluding that the SVM turns out to be the best, without leaving aside the Gabor Wavelet for filtering and extracting characteristics. The SVM algorithm together with its kernels: Linear, Cubic, and Gaussian allow us to perform the facial recognition process, and under the conditions described, better results were obtained with FERET, presuming that it is the background in the images, in turn, the kernel that The best result obtained was the Gaussian with 96% recognition. While with MUCT and under the cubic kernel, a 93.7% recognition was obtained. According to the literature review and the results obtained in the experiments, it is recommended to focus on facial recognition in 2D to 3D, because 2D faces will always be subject to lighting, gestures, pose, etc., that directly influence in the process of a successful recognition.

The present work applies an algorithm for 2D facial recognition applying Gabor for filtering and extraction of characteristics and then SVM for the classification of patterns and achieving an efficient model, considering this as a contribution to the citizen security system.

Finally, based on these efficient Gabor and SVM algorithms, it would be important in the future to apply them in a global 3D facial recognition process, applying projections to a face model and see what results are obtained.

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