International Journal of Computer Applications (0975 – 8887)
Volume 122 – No.1, July 2015

Complete Architecture of a Robust System of Face Recognition

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ABSTRACT
Although human face recognition is a hard topic because of the multitude of parameters involved (e.g. variation in pose, illumination, facial expression, partial occlusions), it is very important to be interested and to invest in it viewed her many fields of application (identity authentication, physical and logical access control, video surveillance, human-machine interface...). The work presented in this paper is in this context. Its objective is the implementation of a complete architecture of a robust face recognition system. In a first time, a new approach has been developed for the detection of faces in a 2D color image. Secondly, is focused on the feature extraction using an original approach which includes the Gabor descriptor and a pose estimator. Finally, to validate this research, the developed system is tested on standard databases: Caltech_Web, AT&T and Color FERET.

Keywords
Face recognition, face detection, Gabor wavelets, pose estimator, Supports Vectors Machines.

1. INTRODUCTION
Face recognition has attracted substantial attention in recent decades from academic research groups and companies specializing in biometrics and security. It is an area of research attracting researchers within different disciplines: psychology, image processing, artificial intelligence, robotics, computer vision, computer graphics and computer networks. This diversity of research disciplines hatched many face recognition algorithms. To get a general idea about most of these algorithms, especially those who have made a true originality and advanced sensitive in this area, one can consult summaries of the state of the art [1] [2] [3] [4] [5].

The implementation of a face recognition system meet criteria of reliability, robustness and speed in any environment is a very open problem nowadays. Indeed, evaluations developed in the programs FERET [6] and FRVT [7], such as the state of the art [8] [9] [10] have confirmed that illumination, facial expression and pose variations are three major problems plaguing current face recognition systems. The work presented in this article is included in this problematic. It aims to design a face recognition system that tolerates these problems. To do it, solutions have been proposed for the different levels of its processing chain.

2. ARCHITECTURE OF AN ARTIFICIAL FACE RECOGNITION SYSTEM
To develop the artificial intelligence systems, scientists are usually based on the natural behavior of human beings. Such is the case of the automatic face recognition that seeks to rival or surpass the amazing capabilities of the human visual system. The latter so that it can identify a person from his face, he needs to have previously associated and memorized the appearance of her face with his identity. This process of learning is easily achieved in humans in a spontaneous and scalable manner. It must be integrated in an artificial face recognition system and carried out in a supervised manner.

The learning or enrollment process is the first module to be executed offline in a face recognition system. While the second module that addresses online, is that of recognition (authentication or identification). The first module allows extracting feature vectors (signatures) from the images of the base reference faces (Gallery); the database of face images of people assumed to be known by the system. These are the extracted feature vectors are learned or stored for use in the classification phase. While the recognition module extracts the feature vector of the query face image which is subjected to the input of the system for the first time. In these two modules, one must browse the processing steps illustrated in Figure 1 and described below.

Face detection and localization: the captured image can contain both the face of the person to recognize and possibly a background. Hence, first of all one must detect the presence or absence of the face in the captured image. If the image contains a face, its location is localized to extract it. This step is performed in two modules (recruitment and recognition).

Feature extraction: this is the key step of the process because the performance of the whole system depends on it. In this step also known as indexing or modeling, is extracted from the detected face image a characteristic vector (signature) that is sufficiently representative of a given face and which models the much more precise than the raw image departure. This new representation of the face must have both the uniqueness property for each person and the property of discrimination between different people.

Learning: in this step, stores the extracted feature vectors of individuals known to the system. During this learning process, each vector stored in the database is associated with a certain personal identity such as name, personal identification number which characterizes the user. This reference database is centralized to a central server or distributed on a smart card only has to recognize the person based on the intended application.

Classification and decision: in these two steps, the system must declare the identity of the person who appears before them without any a priori knowledge about it. To accomplish this task, we must affect the extracted feature of his face to a class from those learned. Each class is associated with an identity. These two steps are executed only in the recognition module.

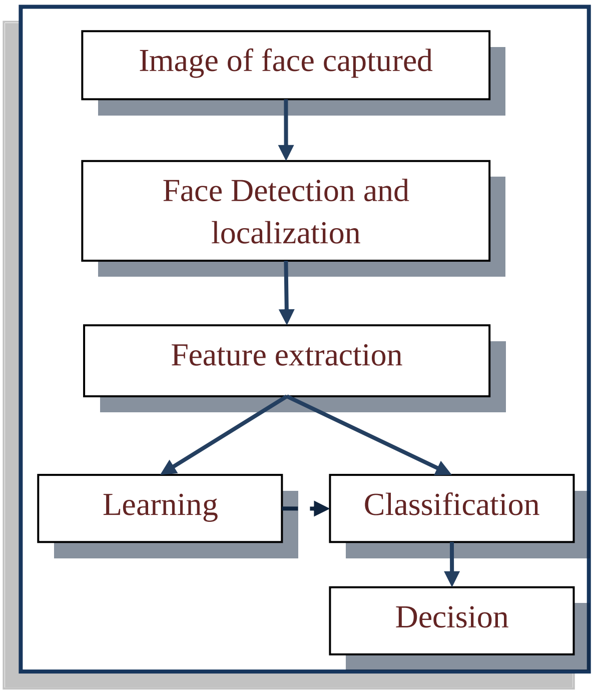

Fig. 1: Basic architecture of an artificial face recognition system

3. THE OPTED APPROACH FOR FACE DETECTION

In order to accomplish the detection procedure in the developed system, we adopted the approach of detecting and locating faces in 2D images to multiple faces published in [11]. In this approach, from the captured color image, a binary image is constructed composed of two classes of pixels (skin and not-skin) by means of a skin pixel detection algorithm. In this algorithm, we implemented a new model of representation of the distribution of skin color. Then a segmentation related and homogeneous skin areas is performed on the binary image using a famous and effective segmentation algorithm; Line of Water Sharing. The images encompassing the regions are located and subjected to face and not-face clustering. In this procedure, the solution of the "Template-matching has been opted which consists in determining the correspondence between the object (face or not-face) and the model of face developed. The definition of this model is based on a share of the overall appearance of a face-type (the presence of the eyes and mouth) and secondly geometric rules applied on the relative positron these traits. Verifying the presence of these traits and their location are provided by a cascade of Gabor filters.

This approach has been tested on the database of facial images Caltech_Web [12] and its performance was compared with those of the Viola and Jones algorithm [13]. The results display a validation of the scientific process used to develop such an approach. We managed to achieve a very satisfactory detection rate with a time of minimum calculation. Moreover, this approach requires no database or learning phase.

4. THE APPROACH OF FEATURE EXTRACTION

4.1 Basic principle of the approach

The algorithm for extracting the feature vectors must be able to tolerate any conditions which may degrade system performance. In particular, in an uncontrolled environment (eg, video surveillance) where appearance to recognize faces varies widely, and this can also be linked to conditions in which the images are acquired and the quality of the acquisition itself. To achieve that purpose, there has been interest in developing a new approach to hybrid nature of feature extraction. On the one hand, a feature vector is extracted from the overall face image containing the most relevant information modeled by descriptor Gabor (Gabor wavelets). Moreover, the pose information is generated by a pose estimator to overcome the problem of large variations in pose. The choice of such a solution is justified by:

- The relevance modeling a face descriptor by Gabor minimizing effects related to changes in illumination, expression and pose no greater than ± 40 °.

- The use of information pose as an input parameter in the classification phase feature vectors facilitates the recognition of faces taken in varying poses. Indeed, the aim of integrating a pose estimator is to adapt the database (Gallery) depending on the pose of the face to be recognized. It is to have a multitude of galleries parameterized by laying the faces and each has its own classifier.

- The details of this approach will be discussed in the following sections after a presentation of integrated tools, namely; descriptor Gabor and estimator pose.

4.2 The descriptor Gabor

Many studies [14][15][16] evoked the great interest of the processing of face images by wavelet (filters) Gabor. The modeling of a face by the descriptor Gabor is realized using the process shown in Figure 2. The face image is subjected initially to a Gabor filter bank (40 Gabor filters with 8 orientations and 5 center frequencies). The 40 responses from filters are then transformed into 40 vectors and concatenated subsequently in one vector. It is this resultant vector which represents the vector descriptor Gabor. View this vector has a very large size (40 x W x H, with (W, H) is the size of the window of a Gabor filter), it must undergo a size reduction. This task is performed by an extraction and reducing algorithm called ACP-ADL double. This algorithm proposed and described in detail in [17], has proved her effectiveness in dimensionality reduction while ensuring discrimination of features vectors.

Finally, the vector obtained after reduction St, represents the feature vector (signature) associated with the face presented to input of the descriptor.

The Gabor filter bank consisting of 40 filters is constructed from the expression following set:

$$G_{u,v}(x,y) = \frac{f_u^2}{\pi k \rho} e^{-\left[\left(\frac{f_u^2}{k^2}\right)x'^2 + \left(\frac{f_u^2}{\rho^2}\right)y'^2\right]} e^{j2\pi f_u x'} \quad (1)$$

With:
$$\begin{cases} x' = x.\cos\theta + y.\sin\theta \\ y' = -x.\sin\theta + y.\cos\theta \end{cases} \quad (2)$$

$$f_u = f_{max}/2^{\left(\frac{u}{2}\right)} \quad (3)$$

$$\theta_v = v\pi/8 \quad (4)$$

f_u and θ_v respectively designate the center frequency and the orientation of the plane wave parameterized by u and v. The parameters k and ρ determine the ratio between the center frequency and the size of the Gaussian envelope along the x and y axes respectively (the standard deviations of the Gaussian: σ_x and σ_y).

Choosing different values for these parameters allows building the Gabor filter bank:

- 8 orientations: $\theta_v = v\pi/8$, $v = \{0, 1, 2, \ldots, 7\}$.
- 5 center frequencies: $f_u = 0.25/2^{(\frac{u}{2})}$ $u = \{0, 1, 2, \ldots, 5\}$.
- Window size (W, H) of each filter is: 128 x 128

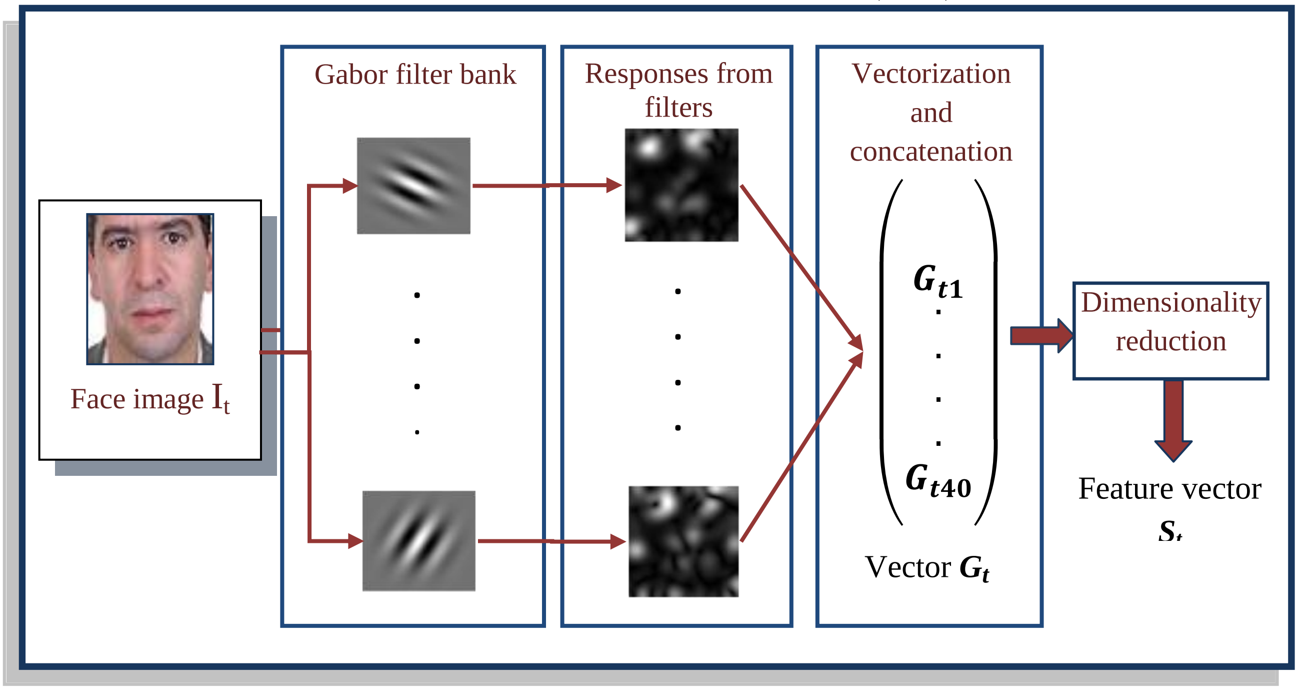

Fig. 3: Process of feature extraction of a face by Gabor descriptor

4.3 Pose estimator

The purpose of a pose estimator is automatic pose estimation of the face (of the head) in images or videos. Geometrically, it consists in estimating its rotation relative to a global repere of reference.

The pose estimation is an essential link in the processing chain for many human machine interface applications. For this reason, that it is currently a multitude of algorithms realizing this function. To have a thorough idea about these algorithms, the reader can refer to the state of the art [18].

In the case of this work, the paving estimator role is to target the classifier associated with the range of poses that it is included the laying of the face to recognize. Accordingly, pose estimator developed for this purpose must estimate in a discrete manner the face pose and give the value closest to that of the face from the following values: 0 °, 30 °, 60 °, 90 °, -30 °, -60 °, -90 ° and not the exact value of the actual pose of the face. Indeed, the pose estimation is introduced in this work in order to facilitate the classification; it is not therefore useful to know the angle of the pose to the degree as the Gabor descriptor already tolerates variations pose which does not exceed ± 40.

The main idea of design of the proposed pose estimator is based on the construction of a supervised learning classifier using Supports Vectors Machines (SVM). To ensure learning of the classifier is first collection some images of faces (face models) in the data base so as to form 7 groups. Each group contains face images that have the closest guidelines to finally define 7 classes {0 °, 30 °, 60 °, 90 °, -30 °, -60 °, -90 }. Then, the images undergo treatment to extract a pose descriptor for each. These descriptors, after reduction that will be stimulated the learning of our SVM classifier. During the presentation of a face image whose pose to estimate (the face is not required that he be present at the time of learning the SVM classifier) at the input of the classifier, it will determine its class membership orientation from its descriptor installation. In other words, the class that provides a score of the highest similarity.

The pose descriptor of is a set of attributes extracted from face images which characterizes the laying information. In such a pose estimator, the Gabor filters were chosen because they are use in advance as descriptor face. However, in defining the descriptor pose, we will not consider all the responses of 40 filters as the case of the vector descriptor Gabor, but selects only the responses of Gabor filters having center frequency respectively (u) and the orientation angle (v) {(1,4); (2,4); (2,4)}. It is these responses that carry useful information to better characterize the pose of a face.

4.4 Functional description of the approach

In this approach illustrated by the block diagram of the proposed approach for feature extraction (figure 3), to recognize the face of a person who appears before the system, the process must run the following steps:

- The image of detected face is submitted to the entry of the Gabor descriptor which is used to return two descriptors vectors:
- The vector concatenating all the responses of the 40 filters. This is the Gabor descriptor vector of the face **Gt**.
- The vector concatenating filters responses as explained in the section of the pose estimator. This vector is the descriptor of the face pose **Gtp**.

- The vector **Gtp** is then reduced and subjected to the input of the pose estimator. this last gives as result a value reflecting the class of the nearest to the actual pose face.
- Depending on the value pose, the vector **Gt** is switched to subspace reduction associated with the pose of class in question in order to reduce her size. After projection of the vector **Gt,** the feature vector St is obtained.
- Finally, the vector undergoes a classification with the specific classifier to the pose face for make a decision about his identity.

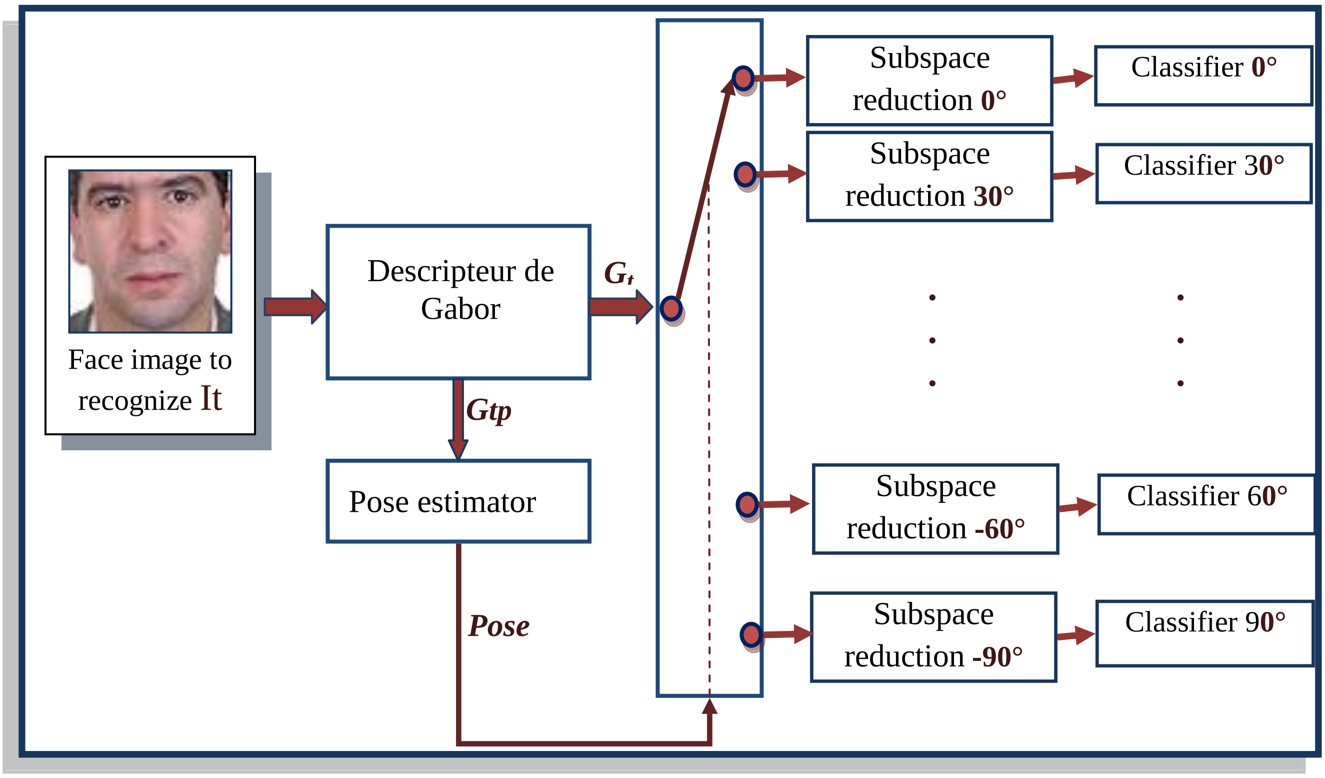

Fig. 3: Block diagram of the proposed approach for feature extraction.

To finish this presentation of this new extraction approach, it should be noted that 7 subspaces reduction and 7 classifiers are built in the enrollment phase to patir of the vectors of Gabor descriptors of face images of the database (gallery). This is of course after distribution of these pictures in 7 galleries parameterized by the pose information.

5. CLASSIFICATION AND DECISION

The Supports Vectors machines (SVM) are a classification methods that have shown its effectiveness in the resolution of some issues related to the field of face recognition, such as the detection of faces in an image [19] [20], detection and location of facial features by the cascading of several SVM classifiers [21] and classification of feature vectors (signatures) faces [22].

For details on obtaining certain mathematical formulas necessary for the implementation of SVM or a good understanding of SVM, the reader may refer to the manuscript of the thesis [23].

The different experiences and the highly satisfactory results obtained by this method of classification have encouraged us to explore this track in this work for the two following purposes:

- The Construction of the classifier used in the pose estimator. In this particular application of SVM, it is desired to discriminate 7 classes each of which is labeled by a pose value amongst the values 0 °, 30 °, 60 °, 90 °, -30 °, -60 °, -90 °. The stimulants of each class are the vectors descriptors of pose of certain exemplary face of the database that have similar poses with an uncertainty of 15 °.
- During the enrollment phase, the separators Hyperplanes of 7 classes are determined. While, for the recognition phase (Test), the target face is assigned to a pose as a function of the position of vector descriptor in the space partitioned into distinct regions by the hyperplanes SVM.
- The classification of feature vectors from the feature extraction algorithm. Similarly for the second application of SVM, the same procedure during the two phases (enrollment and recognition) has been followed, except that in this situation, the number of classes is the number of people (clients) of the Gallery each of which is labeled by an identity.
- In this work, the SVM implemented have the following parameters:
- K. (K-1) / 2 binary and nonlinear classifiers SVM (where K is the number of classes (people) in the reference database (Gallery)).
- The adopted Kernel function is: Polynomial.
- The multi-class classification method is: One versus One.

6. RESULTS, EVALUATIONS AND DISCUSSIONS

As part of the evaluation of face recognition system performance proposed in this work, a series of experimental tests were carried out. But to validate this evaluation, on the one hand, the tests are experienced on the standard databases

AT&T [24] and Color FERET [25], and secondly, comparisons of these performances are dealt with those of some conventional methods of the state of the art. The tests are made as of the following experimental protocols.

6.1 Experimental Protocol 1

This first experimental protocol designed to evaluate the recognition rate and speed of approach proposed for feature extraction in the database AT&T and compare them with those of the conventional method ACP.. The attributes of this Protocol are:

- The database of reference faces (Gallery): 200 face images of the AT&T, the first 5 pictures for each person (altogether 5x40).
- The database of queries faces (Test): 200 face images of the AT&T, the last 5 images for each person (altogether 5x40)

The results of this protocol are summarized in Table 1.

Table 1. Recognition rate in % and time means of identification of both methods: ACP and the approach proposed in the database AT&T

	ACP	Proposed approach
Recognition rate (%)	**80.50**	**99.00**
Time means of identification (s)	**0.0924**	**0.5186**

The study of the results obtained in this first protocol confirms that there is a remarkable increase in the recognition rate. So it is obvious that the proposed approach was able to resolve some problems of ACP method. However, this improvement in the recognition rate is at the expense of the identification time. The latter increases with a value of around 0.4s; this is the time required for the convolution of the input face image with the 40 Gabor filters.

6.2 Experimental Protocol 2

The aim of this experimental protocol is to evaluate the robustness of the proposed approache (without the use of the pose estimator.) to variations: facial expression, illumination and pose. To meet this objective, the Color FERET database is used with the following settings:

- The database of reference faces (Gallery): 100 face images of the base FERET from the FA partition.
- The database of queries faces for the variation of facial expression: 50 face images of the FB partition.
- The database of queries faces for the variation of illumination: 50 face images of the FC partition.
- The database of queries faces for the variation of pose: 270 face images from set FERET Pose of 30 people (9 pose per person).

The results of this protocol are summarized in Table 2.

Table 2: Recognition rate in % of both methods: ACP and the approach proposed in the database Color FERET with a different variations of facial appearance.

	Variation d'expression faciale	Variation d'illumination	Variation de pose
ACP	**64,50**	**51,00**	**33,40**
Proposed approach	**90,00**	**87,50**	**81,30**

By analyzing the results presented in Table 2, we see that there is a great improvement of recognition rate with the approach proposed same in the presence of strong variations in facial appearance.

For the recognition rate 90% obtained for the change in facial expression, this is a very satisfactory rate.

The recognition rate of 87.50% achieved in the case of the change of illumination remains a reasonable rate considering the strong lighting variations present at FC partition.

Regarding the recognition rate of 81.30% obtained at the time of test of the pose variation with the proposed approach without the pose estimator, it appears that is a modest rate. A reasonable solution to increase this rate is in the integration of the pose estimator already mentioned as a key tool in the system architecture.

6.3 Experimental Protocol 3

The presentation of the experiments performed in this work is ended with thus protocol which will allow to evaluating the performance of the pose estimator proposed. Therefore validate its impact on the identification string, especially in an environment where there are large variations in pose.

To ensure learning SVM classifiers of the estimator, a set of 70 facial images (the poses models) is collected so as to form 7 groups. Each group contains 10 face images that have closest to finally define 7 classes of orientation { -25 °, -60 °, -90 °, 0 °, + 25 °, + 60 °, + 90 °}.

During testing, it was subjected to the input of the estimator a serie of 55 face images extracted at random from the database Color FERET (test sets). The faces contained in these images have different poses: -90 °, -60 °, -45 °, -25 °, -15 °, 0 °, + 15 °, + 25 °, + 45 °, + 60, + 90 (10 images per pose).

The experimental results obtained by the classifications pose estimator are summarized in the following two rates;

- The correct estimates rate: 92.72%.
- The false estimates rate: 7.27%.

The results of tests of the latter Protocol declare the notable effectiveness of the pose estimator developed viewed the value of the rate of correct estimates obtained.

7. CONCLUSION AND PERSPECTIVES

The presented results confirm the interest of new approaches proposed for developing such a face recognition system. They helped eventually leading to a robust system to variations in pose, illumination and expression. This robustness is manifested practically in the precision in terms of recognition rate.

In future works, an extension of the developed face recognition system is suggested for the context of the video. Indeed, if want to envisage the system for application such as video surveillance, it is mandatory to test it on video sequences taken in uncontrolled real environment.

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