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Face Recognition in a Mixed Document based on the Geometric Method

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Abstract

Currently, human face recognition is considered one of the most important tasks to take up the challenge of pattern recognition. The ease and accuracy with which one can identify friend and foe, even under adverse conditions, are some of the most amazing capabilities of the human visual system; the purpose of face recognition is to design computer systems capable of matching human beings in this area.

In this work, we present an implementation of a system of people identification through recognition of human faces. We have developed a geometric model of the face based on a set of characteristic features extracted from facial image. In fact, it is a geometric method based on measurements concerning three important organs of the face namely: the eyes, the nose and the mouth.

The choice of these characteristic features is based on the results of cognitive psychology research concerning the human visual system. Given that the eye, nose and mouth areas are particularly important for identification, the features used cover all such three areas. Among key measures that have been taken, there are particularly the following: the distances separating these organs from one another, the position and width of the nose, the position and width of the mouth, the thickness of the eyebrows etc.

Keywords: *Face Recognition; Hybrid Method; Template Matching; geometric Method; Neural Networks*

1. Introduction

A biometric system is a pattern recognition system that uses the biometric data of an individual. In an application, a biometric system can operate in one of the following modes:

-The enrollment mode: in which the system aims to collect biometric information on the persons to be identified.

-The verification or authentication mode: which corresponds to a "one-to-one" comparison, in which the system validates the identity of a person by comparing the biometric data entered with the biometric model of this person stored in the database of the system.

-The mode of identification: which corresponds to a comparison "one to N", in which the system recognizes an individual by matching it with one of the models of the database.

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Thanks to the growing computing power of computers, biometric applications have become more and more numerous and effective [1]. They provide a higher level of security with regard to logical access (computers, bank accounts, sensitive data, etc.), or physical access (secure buildings, airports, laboratories, *etc*.).

Biometrics refers to the use of morphological or behavioral characteristics to determine or verify the identity of a user [2]. It is a comprehensive technique to establish a person's identity by measuring one of their physical characteristics. There may be several types of physical characteristics, some more reliable than others, but all must be inviolable and unique to be representative of one and the same individual. On the other hand, as we will see, the physical characteristics are far from being so perfect and so precise, and we soon reach the limits of these techniques. The face is the biometric characteristic commonly used by men to recognize themselves. More generally, the problem of identifying people today occupies a preponderant place in our society. Ensuring the identity of a person is necessary in many areas.

In order to guarantee the identity of an individual by limiting the risks of usurpation, many authentication systems are put in place in everyday life. Traditionally, these systems are classified into three categories [3]: systems based on a priori knowledge of the individual, systems based on the possession of an object and the third type of authentication is based on what the 'we are. It is the biometric characteristics of an individual (fingerprints, face, iris, ...) that allow him to be authenticated. These have the distinction of being universal (everyone has them), unique (two people cannot share the same biometric feature), permanent (they do not change or little over time).

Generally speaking, in terms of facial recognition, researchers have not yet achieved a performance comparable to that of men. But in recent years, research in this area has shown that the difficulties encountered are almost the same for almost all methods.

Yang *et al.*, [4] Proposed a classification of facial location methods. Among them:
The method based knowledge of the different elements that make up a face and the relationships that exist between them.

[5] The problem with this type of method is that it is difficult to define a face in a unique way.

Methods that use the same principle as the previous one but are based on particular models. These methods have the advantage of being executed very quickly but require a long training time. The methods belonging to this category have shown good results compared to the other type of method [6].

The recognition of faces in a mixed document (text + images) is an essential and crucial treatment which consists of looking in this document at the position of the faces and extracting them in the form of a set of images in order to process them.

The facial recognition process can never become fully automatic unless it has been preceded by an effective face detection step. Indeed, an automatic facial recognition system is divided into three subsystems: face detection, feature extraction and facial recognition.

Face recognition poses the problem of the location of the faces present in an input image. The interest of the facial localization goes beyond the application of this work. Its utility manifests itself in various areas ranging from video surveillance to interactive gaming. The first difficulties faced by face detection methods are the variations in pose (profile, face), expression, facial rotation, age and illumination. This last type of difficulty can be overcome by pretreatment of normalization and compensation of illumination.

Face detection methods can be subdivided into four categories [7]:

- Approaches based on acquired knowledge: the main parts to which this method refers to their characteristics, as being the characteristics of the face, are the nose, the mouth and the eyes. These methods are designed primarily for the location of the face.

- Model matching approaches: These methods consist in calculating the correlation between the candidate image and the model. They use an algorithm that calculates the

luminance ratios between the face regions and keeps the directions of these ratios (for example, Region 1 is lighter or darker than Region 2) [8].

-Approaches based on appearance: These methods generally use machine learning techniques. They are used for detection. The main idea of these methods is to consider that the problem of face detection is a classification problem (face, non-face). One of the most well-known approaches to face detection is the Eigen face, which consists of projecting the image into a space and calculating the Euclidean distance between the image and its projection.

- Approaches based on invariant characteristics: These approaches are mainly used for the localization of faces. The algorithms developed aim to find the existing structural characteristics even if the posture, the point of view or the lighting conditions change. Then, they use these invariable features to locate the faces.

Unlike the human visual system, an automatic face recognition system adds a learning step during which it associates the look of the face with the identity of a person which requires a database of known people storing labeled images of identities [9].

Nowadays, the location of faces in an image has become an important research topic. In this work, we present a system for the detection and recognition of faces in a mixed document (text + still images) based, in its first phase of detection, on the hybrid method allowing to distinguish, from the mixed document, the same color that the skin then in second phase on the method Template Matching allowing to distinguish among these figures only those which contain faces to be able to treat them in phase of classification. In this phase, we developed a geometric model of the face based on a set of characteristic points extracted from the image of the face. The identification procedure consists of calculating the K nearest neighbors of the test individual. Our system was inspired by the system developed by the method WHO_IS [10] which gave a success rate of 86% and because this system took into consideration the three points ends of the mouth which are points that can vary according to the state of the mouth, it was thought, for our system, to replace these points by others considered invariant (center point of the mouth, the points determining the distance between the center points of the eyelids) whose purpose is to improve the recognition rate. Our system is tested on a sample of 200 faces. A correct recognition rate of 92% was obtained. In this comparison, our system uses, for the classification phase, the neural networks and the nearest neighbor K method.

2. Extraction of Parameters

2.1. Automatic Face Recognition Process

The face is a dynamic entity that changes constantly under the influence of several factors. Every automatic face recognition process must take into account several factors that contribute to the complexity of its task. Figure 1 illustrates the general approach taken to make such systems.

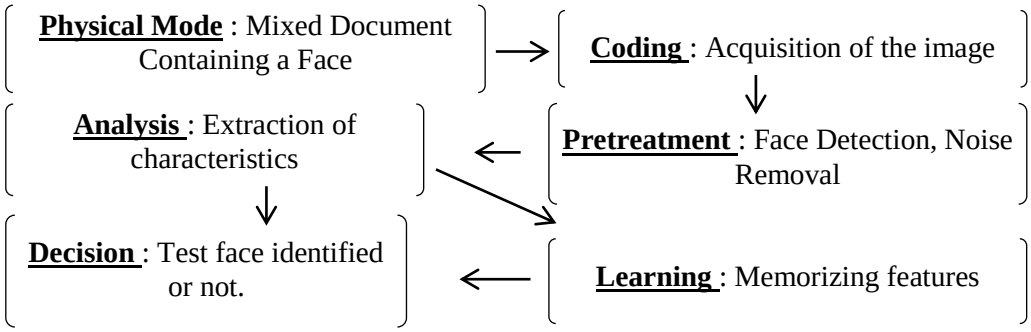

Figure 1. General Scheme of a Face Recognition System

2.2. Existing Methods

Several approaches have been proposed, we distinguish, in general, two categories: Global methods and geometric methods.

2.2.1. Geometric Methods

Geometric methods are also called feature methods, with local characteristics. The analysis of the human face is carried out by the individual description of its parts and their relations. Which corresponds to the way in which the human being perceives the face, that is to say, to our notions of facial features and parts like the eyes, the nose, the mouth, etc. Most of the work has focused on extracting features from a facial image and defining a suitable model to represent that face. A number of automatic and semi-automatic strategies have modeled and classified faces based on standardized distances and angles between feature points. The strategy is described as automatic or not depending on whether the point extraction phase is done by the computer or is assisted by an operator. This phase is the key step in the process because the performance of the entire system depends on the accuracy with which the relevant information is extracted [10].

Taking into account the peculiarity of the face as a natural form to recognize is the advantage of these methods. And the difficulty experienced when it comes to taking into account several views of the face and the lack of precision in the phase "extraction" points are their major drawback.

2.2.2. Global Methods

Global methods use the principle that the whole face is the source of information, and this without segmentation of its parts. Indeed, a gray level image is represented by a vector, the colors are not generally used in these methods which simplifies a large number of operations. Among these methods we distinguish the Eigen Faces method, the DCT (discrete cosine transformation), Neural networks, LDA [11].

2.2.3. The WHO_IS System

The system WHO_IS possesses is characterized by the fact that it treats only the front view of the face, Invariant to the presence of the parts or element disturbing to the recognition such as the mustache, the beards and indifferent to the facial expressions, also invariant to the wearing a hat, cap, scarf, glasses [10]. The WHO_IS system is based on the one proposed by Kamel *et al.*, (1993) where they argue that 9 well-chosen points are sufficient to identify a face. But for larger databases, the number of feature points must be larger. Thus the system WHO_IS reused the 9 points of the model of Kamel *et al.*, Plus 3 points they added. This is as shown in Figure 2.

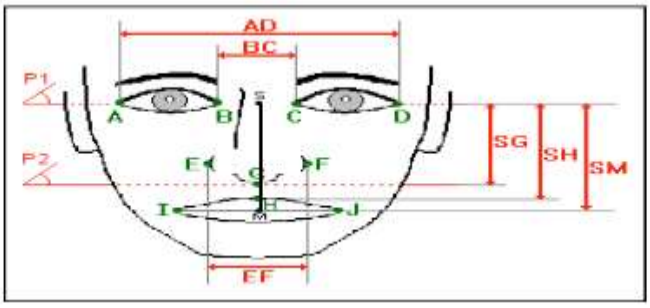

Figure 2. Geometric Model of the Face -WHO_IS System [10]

The correct recognition rate of WHO_IS is 86%. The method used in this system has the advantage of being simple and robust, and the results obtained globally provide a

quality solution. Compared to other systems, WHO_IS is characterized by some advantages, namely, on the one hand, the large size of the sample compared to other systems, on the other hand, there are no constraints on the environment as it is the case for other systems, and finally WHO_IS is invariant to the type of hairstyle, the wearing of hat, scarf, glasses.

3. Classification Approaches

The classification is the assignment of a specific class or not a given face class: the class here is a person with face images in the database and non-class in the case where the face belongs to n ' any class. This allocation requires the introduction of a similarity measure that can be exploited by techniques, among them the nearest neighbor K techniques and the neural network technique.

3.1. The Techniques of the Nearest K Neighbors

The nearest-neighbor K (KNN) method [Cover & Hart, 1967] is part of supervised learning that has been used in many applications, including data mining, statistical form recognition, and processing. images [12]. Its purpose is to classify target points (unrecognized class) according to their distance from points constituting a learning sample (*i.e.*, whose class is known a priori). It is an intuitive supervised classification approach, often used in machine learning. This is a generalization of the nearest neighbor method (NN). NN is a special case of KNN, where k = 1.

The KNN classification approach is based on the assumption that each case of the learning sample is a random vector from Rn. Each point is described as

$$x = < a_1(x), a_2(x), a_3(x), \ldots, a_n(x) >$$

where $a_i(x)$ corresponds to the value I of the $i^{ème}$ attribute. $a_i(x)$ can be either a quantitative variable or a qualitative variable.

In order to determine the class of a target point, each of the k closest to x_q points to a vote. The class of x_q corresponds to the majority class.

To identify the class of an entry, the algorithm, of the nearest K neighbors, selects the class to which belongs the majority of the k nearest neighbors.

The K-nn algorithm is considered one of the simplest machine learning algorithms. However, it is expensive in terms of calculation, especially when the size of the training set becomes large, which makes the classification task very slow.

3.2. The Technique of Neural Networks

The neural network technique is a nonlinear signature extraction technique used for facial recognition [9] [13]. It is based on a set of artificial neurons (RNAs). He was inspired by the physiology of the nervous system so perfectly created and conceived. The formal neuron, introduced by J. McCulloch and W. Pitts in the 1940s, forms the basis of RNA architecture.

Based on the theory of analogy, the formal neural model was introduced to attempt to replicate the function of neuronal cells. In the biological nervous system, it is considered that the neuron is the basic element ensuring both the propagation and the processing of information. Each neuron receives electrical or chemical stimulation from other neurons at the level of the dendrites attached to its cell body via synapses or inter-neuronal linkages. When the neuron has received a sufficient number of simulations, it transmits information to neighboring neurons by means of a nerve impulse that propagates along its axon. (Figure 3. (a)).

A formal neuron is a nonlinear algebraic function (parameterized and bounded) of real variables called inputs, which attempts to reproduce this mode of operation. A formal

neuron performs a weighted sum of input signals that arrive there. This weighted sum serves as a parameter for a function, often nonlinear, which transforms it into a new signal transmitted at the output (Figure 3. (b)).

With regard to the functioning of the biological neuron, the function appearing after the summation of the inputs is called the activation function.

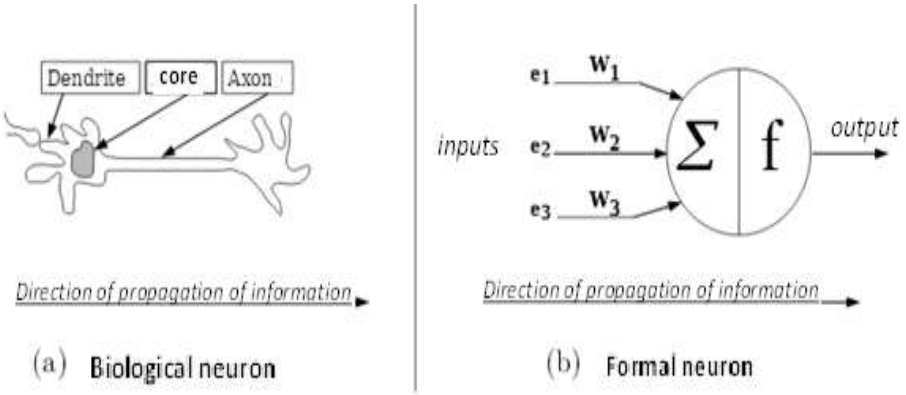

Figure 3. Analogy between the Biological Neuron and the Formal Neuron [9]

The formal neuron is an elementary unit of a neural network. It performs the weighted sum of its entries because the value of this sum is compared to a threshold. The output of the neuron is as follows:

$$\mu = \sum_{i=1}^{n} w_i \cdot e_i - \theta \quad (1)$$

$$Y = f(\mu) \quad (2)$$

Such as:
e_i : Element of the input vector,
$i = 1..n$: Formal neuronal inputs,
Y: output,
w_i : Weighting parameters,
f: The activation function.

4. Facial Recognition System Proposed

The purpose of the application is to allow the user of our system to detect and recognize the faces of people in a mixed document containing text and images with or without faces. A typical scenario of the use of this system takes place in five phases.

4.1. Segmentation of the Skin Regions.

The Hybrid method: it is a considerable method because it allows a significant reduction of the space of search of the faces which will be limited only to the sections of color flesh. The performance of the face detection system is therefore closely related to the results obtained during the segmentation of the skin color.

Skin-based methods reduce the search space of the face area in the image. In addition, the color of the skin is robust information against rotations, changes of scale, and partial occlusions. Several color spaces can be used to detect, in the image, the pixels that have the color of the skin. The effectiveness of the detection depends essentially on the chosen color space. Among the most used color spaces, the RGB space (or RGB), it consists of representing the color space from three monochromatic radiations of colors:
Red-Green-Blue. For example, skin is classified in the RGB color space using the following rules [14]:

$$R > 95 \text{ et } G > 40 \text{ et } B > 20 \text{ et } \max\{R, G, B\} - \min\{R, G, B\} > 15 \text{ et} \quad (3)$$

$$abs(R - G) > 15 \text{ et } R > G \text{ et } R > B$$

In this paper, we present a comparative study on the detection of skin color by thresholds according to the RGB color spaces. The thresholding step will provide us with binary images whose skin sections will have the highest gray level of 1 (white) while the other (non-skin) sections will have the lowest gray level of 0 (black).

4.2. Segmentation of the Face Regions

The Template Matching method whose principle is as follows: it is a digital image processing technique to find small parts of an image that corresponds to a model image. It can be used in manufacturing as a part of quality control, or as a means of detecting objects in images *etc*. This is, given any image and a predefined model, to determine if this model is in the image to be tested and find the position.

4.3. Face Detection

In this phase, face detection is established by pairing the "Template Matching" template, which compares the intensity of the pixels between a predefined template and several sub-regions of the image to be analyzed. This process consists in practice of carrying out several scans covering the entire area of the image. The most favorable places for the presence of faces will therefore be easily identified by minimum distances between the template and the underlying image.

4.4. Extraction of Facial Features Detected

The extraction step is the key step in the process because the performance of the entire system depends on it. In this step also known as indexing or modeling, is extracted from the image information of the face that can model the face of a person by a measurement vector that characterizes it (characteristic vector or signature).

The judicious choice of the extraction method is extremely important since the next step (classification) will be made only on the basis of the values of these vectors.

The characteristic points used are chosen based on the results of cognitive psychology research concerning the human visual system. Notably the fact that the area of the eyes, the nose and the mouth are important for identification, the points used cover all three regions to which the region of the Franc and that of Cécille have been added. The characteristics, used by our system, to identify a face are 17 deducted based on 15 points (the 12 points of the model WHO_IS [10], having a recognition rate of 86%, which is based on the model of Kamel *et al.*, Having used only 9 points and who had a recognition rate of 66%, and to which we added 3 other points including the centers of the two Cécilles and a midpoint of the franc. in advance, that the recognition rate can be improved with more points that will slightly increase the number of features of a face.

4.5. Classification

The classification is the assignment of a specific class or not of a given face class: the class here is a person with face images in the database and the non-class in the case where the face belongs to any class. This distribution requires the introduction of a similarity measure.

4.5.1. Neural Networks

The way a diabolo-like RNA can be used to extract the signature associated with a face has been described previously. Learning makes it possible to adapt the network parameters during the registration phase, in order to then discriminate the signatures presented on its entries. This is done iteratively. A face is selected from the learning base,

whose signature is placed at the entrance of the network. The outputs of the network for this value of its inputs are calculated then the evaluation of the error functions considering that the ideal outputs are all zero except that which corresponds to the class to which the individual belongs. To adjust the network parameters, the standard error propagation technique is then used. This procedure is iterated by presenting at the input, several times and in a random order, all the signatures extracted from the images of the database.

The signature of the target face during the identification phase is calculated and applied as input to the discriminant RNA. The output of the network that takes the maximum value indicates which class the target belongs to. The introduction of a threshold on the value of the maximum output makes it possible to determine if the target image does not correspond to any person known from the database.

4.5.2. K-nearest Neighbors

The k-nearest neighbor algorithm (KNN) is a method of learning by instance [15]. It does not include a learning phase as such. The characteristics of the faces forming part of the training set are only recorded. When a new face arrives, its characteristics will be compared to the learning characteristics using a similarity measure. Its nearest neighbors are then considered: we observe their category and the one that comes back most among the neighbors is assigned to the face to classify. The method therefore uses two parameters: the number k on the one hand and the similarity function on the other hand.

5. Results and Discussions

5.1. Objectives and Consequences

The purpose of the application is to allow the user of our system to detect and recognize the faces of people present in a mixed document containing text and images including or not faces. A typical scenario for using this system is five phases.

5.1.1. Segmentation of the Skin Regions

Based on the Skin Color Hybrid method developed in the previous chapter, this phase consists in sectioning pixels representing the skin color from a mixed input document (Figure 4-(a)) and then filtering the color pixels of independent skin [16] as shown in Figure 4-(b) shown below.

5.1.2. Segmentation of the Face Regions

Based on the Template Matching Method, this phase focuses on eliminating non-face color skin areas. Figure 4-(c) is an illustration for this phase.

5.1.3. Face Detection

In this phase, the detection of the faces is established by matching the model "Template Matching" which is interested in comparing the intensity of the pixels between a predefined model and several sub-regions of the image to be analyzed. This process consists of several scans covering the entire surface of the image. The most appropriate places for the presence of faces will thus be easily identified by minimum distances between the template and the underlying image as shown in Figure 4-(d) and Figure 4-(e).

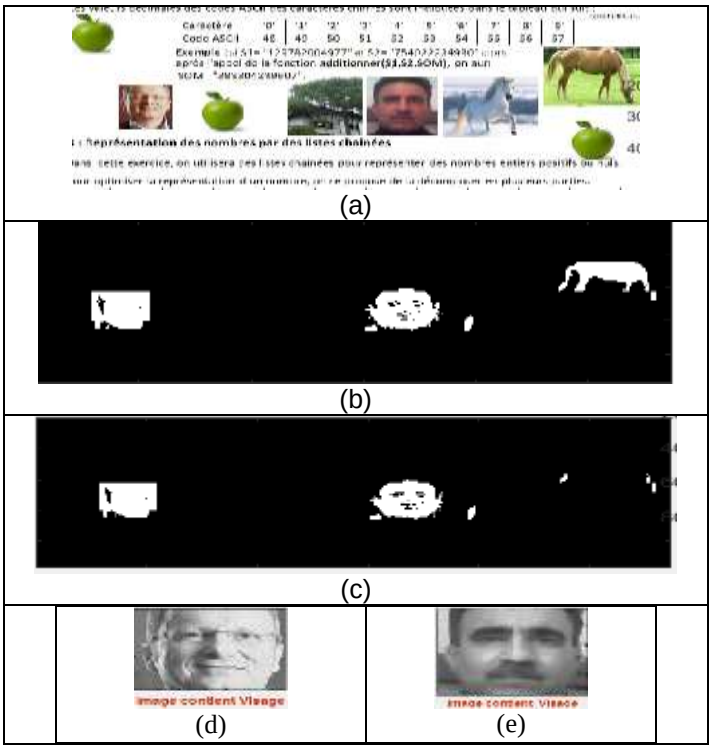

Figure 4. Example of Face Detection in a Mixed Document by Template Matching Method

5.1.4. Extraction of Facial Features Detected by our Geometric Model

From the 15 points determined by our system, previously reported, which has been deduced using the 'Templette Matching' method as shown in Figure 6 presented below, it has been found that they can be classified as two types:

1st type: 11 invariant positions. These are the following positions:

• The four positions P1, P2, P3, P4 and P12 determined by the ends of each eye.

• The positions P5, P6 and P7 determined by the nose.

• The positions P8, P9 and P10 determined by the mouth.

2nd type: 4 other positions, variants, these are the following positions:

• The positions P11, P13, P14 and P15 determined by the mouth and the eyes from which invariant distances have been determined added to the facial characteristic vector used for facial recognition.

Figure 5. Extraction of the Different Positions Exploited by our System

From these different positions we have determined, therefore, 17 characteristics, invariant, which we considered as characteristic vector of the face used for the recognition of the face by our system, it is:

- Characteristic ranges: distances determined by the points of the eyes and the center point of the mouth (between the positions P1, P2, P3 and P4 and the position P10);

- Characteristic ranges: distances determined by the points of the eyes and the low point of the nose (between the positions P1, P2, P3 and P4 and the position P7);

-Two characteristics: distances determined by the points of the nose and the center point of the mouth (between the positions P5 and P6 and the position P10);

A characteristic: distances determined by the ends of the nose (between the positions P5 and P6);

-Two characteristics: distances determined by the points of the eyes and the middle point of the two eyes (between the positions P1 and P2 the position P12);

A characteristic: distances determined by the center axis of the head (between the positions P12 and P10);

- A characteristic: distances determined by Cecile points (between positions P13 and P14);

-Two characteristics: distances determined by the Frank center points and the Right ends of the left eye and Left ends of the Right eye (between points P15 and P2 and then between P15 and P3).

5.1.5. Classification

The classification is the assignment of a specific class or not a given face class: the class here is a person with face images in the database and non-class in the case where the face belongs to n ' any class. This allocation requires the introduction of a similarity measure.

K-nearest neighbor: The algorithm does not construct a classification model but is based on values found in storage or memory. To identify the class of an entry, the algorithm selects the class to which belongs the majority of the k nearest neighbors. The K-nn algorithm is considered one of the simplest machine learning algorithms. However, it is expensive in terms of calculation, especially when the size of the training set becomes large, which makes the classification task very slow [16].

The neural networks: It is a set of interconnected neurons for the formal resolution of complex problems such as pattern recognition or natural language processing, adjusting weights in a learning phase. The functioning of the neural network based on the functioning of biological neurons and is materialized in the form of a computer algorithm. eural networks are known for their strength in the field of facial recognition.

-Biological neurons: In very simplistic terms, a neuron is a biological cell characterized by synapses, dendrites, axons and nuclei. Biological living cells are neurons that are interconnected by links called axons [13] driving electrical signals from the output of one neuron to the input (synapse) of another neuron.

-Neuron artificial: A neural network consists of simple elements, operating in parallel, that have been inspired by the biological nervous system. It is a weighted oriented graph whose nodes symbolize the formal neurons. These have an activation function to influence other neurons in the network. The connections between the neurons, the so-called synaptic links, propagate the activity of the neurons with a weighting characteristic of the connection.

It can cause a network of neurons for a specific job (*e.g.*, character recognition) by adjusting the values of the connections (or weight) between the elements (neurons).

5.2. Database

Our system has been tested on a large part of the feretc-color database. We used 200 faces in this database, an extract of which is shown in Figure xx. All of these faces are

spread over 40 different classes of people with 5 different faces each, depending on the facial expressions of the person and the distance characterizing the image of the same person within reach.

Figure 6. Extract from the Database used by our System

This database is transformed during processing, into a learning base which aims to reduce the time of the classification phase to allow our system to compare, in a short time, the face in with all faces of the database used.

5.3. Results and Discussions

Initially, we performed several tests, only with just 12 points of the WHO_IS method, the success rate based on these 12 points was a little less close to the rate achieved by the method WHO_IS, because of the database used by our system which is more important in terms of number of faces compared with that of the method WHO_IS, which pushed us to increase, more, the number of points to reach 15 points from which we have determined 17 characteristic to form the characteristic vector of the face so the results are greatly improved as shown in table 1 presented below.

Table 1. Different Face Recognition Rates Performed by our System

Descriptor	**Neural Networks**		**K-NN**			
			Euclidean		**Manhattan**	
	R.R	**E.R**	**R.R**	**E.R**	**R.R**	**E.R**
PCA	88%	12%	86 %	14%	87 %	13%
Geometric method	92%	8%	90%	10%	91%	9%

After analyzing the results achieved by our system, we found for each of these classifiers the results are important with a slight favor for the neural networks. And for each of the descriptors the results are equally important with a favor for the geometric method.

6. Conclusion and Perspectives

The purpose of this article was to achieve face recognition in a mixed document. This process had to be part of a complete system of detection / recognition processing in real time information from a document that contains both text and images with faces.
We focused on developing a fast and reliable facial recognition method. For that we first chose an image descriptor, in order to be sufficiently informative but inexpensive in computing time. We first implemented the PCA descriptor that is conventionally used in this area: The results were not satisfactory, which pushed us to develop a descriptor

adapted to our case, faster in computing time. That's why we explored a new track with a geometric descriptor.

Next is the classification task that uses the information provided by the upstream descriptor. Here again we have implemented the most popular methods of this last decade: methods of k-nearest neighbors and neural networks.

All of these methods have been implemented to be tested and validated. Numerous combinations have been experimented, by changing descriptors and classifiers, which has made it possible to highlight certain facts.

Regarding the image descriptors, we tested two: the PCA and a geometric descriptor based on distances between different invariant points of the face. This is the geometric descriptor that has the best performance for this application. However, the other two descriptors get close results. At the end of this work, the first, trivial, observation is that this type of challenge is very difficult. If it seems almost innate to interpret what we see and act accordingly, the task is much more difficult from a vision system.

The great variability of the faces (position, lighting, facial expressions ...) is a great difficulty to train a classifier and find a suitable model. Improvements could certainly be made by using better descriptors or by training classifiers on gigantic learning bases. But the use of such methods, which are more information-rich, is still impossible for us in terms of computing time. There must be a compromise between calculation time and performance.

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