Face detection by neural network trained with Zernike moments

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Abstract: We present in this communication a new method to localize a face in an image. The originality of work presented consists on the use of vectors of geometrical moments like entries to a Forward Back-Propagation neural network which provide at its output layer a vector of co-ordinates in (R,θ) representing pixels surrounding the face contained in the treated image. Very known for their orthogonality and their rotational invariability, the geometrical moments of Zernike are calculated here to form the feature vectors supplied to the input layer of the network. The experimental results of the application of our method on images of the XM2VTS database are presented.

Key words: Image processing, Face detection, Geometrical moments, Zernike moments, Neural network.

1 Introduction:

Face detection in an image or in a sequence of images, is being of great importance in the applications which treat aspects related to the Human-Machine communication. Thus, for face recognition (identity check), analysis of expressions or to take movements of face parts into account (gesture communication); localization of face in image or in video acquired by various peripherals (cameras, scanner, infra-red...) is necessary to the achievement of these operations. Several ways were explored by the researchers. Classification, according to Hjelmas and Low [1], allows distinguishing two principal approaches. The global approach which consists in entirely seeking the face and the components approach which consists in finding the face through the localization and the regrouping of its components (eyes, nose...). According to one or the other of these approaches, each developed method exploits one or more characteristics of face like colour, shape, movement, ...

Method presented in this communication exploits geometrical characteristics of the face in a global way. It carries out the operation of face localization through the use of a neural network trained beforehand, on the basis of vectors of geometrical moments, to deliver on its output layer a number of pixels representing a probable contour of the required element.

Geometrical moments are known for their capacity to compress the geometrical information, contained in the image treated, in a rather reduced vector of parameters through the projection of the image on an orthogonal basis [2]. Here in our present work we are particularly interested by the geometrical Zernike moments since in more of their orthogonality, they allow, through simple transformations, to obtain a complete and orthogonal base invariant in rotation, translation and scale [1], [3]. This characteristics makes them very adapted to the training of classifiers who often need, on their input layer, feature vectors reduced in size but rather representative of the element subject to the classification.

In section 2 we will explain the formulation of geometrical moments of Zernike and the possibilities of their computation in a fast and effective way, in section 3 we will introduce the relationship between face detection and Zernike moments and then we will give the description of the method suggested and the way of its implementation. Section 4 shows the results and section 5 the conclusion.

2 Formulation and implementation of Zernike moments :

Zernike moments form part of the general theory of the geometrical moments. They were introduced initially by F. Zernike [4]. At the difference of the general geometrical moments, those of Zernike are built on a set of orthogonal polynomials. These polynomials are the basic elements of the construction of an orthogonal base given by the relation **(1)**

$$V_{n,m}(x,y)=V_{n,m}(\rho,\theta)=R_{n,m}(\rho).e^{j.m.\theta} \qquad (1)$$

where :

$$\begin{cases} R_{n,m}(\rho)= \sum_{k=|m|}^{n} \dfrac{(-1)^{(n-k)/2}.(n+k)!}{|(\dfrac{n-k}{2})!(\dfrac{k+m}{2})!(\dfrac{k-m}{2})!}.\rho_k \\ \\ \rho=\sqrt{x^2+y^2} \qquad and \qquad \theta=arctg(y/x) \end{cases} \qquad (2)$$

with: $\mathbf{n \geq 0}$, $\mathbf{m \neq 0}$, $\mathbf{|m|<n}$, $\mathbf{n-|m|<n}$ and $\mathbf{(n\text{-}k)}$ even.

$R_{n,m}(\rho)$ is the orthogonal radial polynomial, **n** is the order of the moment and **m** the factor of repetition (the smoothness of the required details) at this order. ρ and θ are respectively the radius and the angle of treated point of the function.

The orthogonality of this base is assured only inside the unit circle so the bi-dimensional function to be projected must be remapped inside it. In case of a discrete function, such an image, this transformation between the relative co-ordinates (**i**, **j**) of the initial image pixels and   (**x$_j$, y$_i$**) of the remapped one can be carried out through **(3)**.

$$x_j=c+\dfrac{j.(d-c)}{(N-1)} \quad and \quad y_i=d-\dfrac{i.(d-c)}{(M-1)} \qquad (3)$$

With (**M,N**) dimensions of the function to be projected, **i** and **j** indices of the point to be remapped and (**c,d**) couple of parameters allowing to remap the function inside, completely (c=-1√2 and d=-c) or partially (c=-1 and d=1), of the unit circle.

The projection of a numerical function on the basis functions of (1) gives the Zernike moments $Z_{n,m}$

according to **(4)**:

$$Z_{n,m} = \frac{n+1}{\pi} \sum_{x_j^2+y_i^2 \leq 1} \sum f(x_j,y_i).V^*_{n,m}(x_j,y_i) \qquad (4)$$

* : denotes the complex conjugate of the function where : $f(x_j,y_i)$ is the numerical function to be projected, x_j and y_i were defined on **(3)**, n and m are respectively the Order and repetition on the Zernike moments.

However, traditional formulation of Zernike moments is very easy to implement but its computational cost is very high and so less adapted for treatments which requires fast execution. This major handicap pushed the researchers to try to find a formulation more suitable to enhance the speed computation. Mukandan et al. [5] proposed a recursive algorithm to calculate the Zernike moments in polar co-ordinates. Belkasim et al. [6] used a radial and angular expansion orthonormal polynomials of Zernike to propose a fast recursive algorithm. Gu et al. [7] used a circular transformation of the relations suggested in [5] to lead to a faster algorithm. Finally, Amayeh et al. [8] proposed an algorithm which is as fast as the precedents but which have the advantage of preserving accuracy of computation on the same level as the traditional formulation. To do so, no quantification on the parameters angle and radius (ρ,θ), was introduced. The safeguarding of the precision ensures maintenance of the orthogonality of the build base. To enhance the speed computation and, in the same time, preserve the precision, the proposed formulation is based on the detection, in the process of obtaining the moments, of general terms whose calculation is done in the same way during all the iterations. These terms are then calculated only one time and are memorized in a table directly addressable during the realization of the various iterations.

In our work, we adopted the last formulation.To lead to this form of representation, the preceding equations are rewritten and reorganized as the equation **(5)** shows it.

According to this formulation, we need only

$2.(\frac{n}{2}+1)^2 +(M^2-1)$ additions and $\dfrac{n^2.M^2}{2}+2.M^2.n$

multiplications to compile Zernike moments up to order **n** for an image of dimension (MxM) [8].

$$Z_{n,m} = \frac{n+1}{\pi} \sum_{x^2+y^2 \leq 1} \sum \left(\sum_{k=|m|}^{n} \beta_{n,m,k} . \rho^k \right) e^{-j.m.\theta} . f(x_j, y_i)$$

$$= \frac{n+1}{\pi} \sum_{k=|m|}^{n} \beta_{n,m,k} \left(\sum_{x^2+y^2 \leq 1} \sum e^{-j.m.\theta} . \rho^k . f(x_j, y_i) \right)$$

$$= \frac{n+1}{\pi} \sum_{k=|m|}^{n} \beta_{n,m,k} . X_{m,k} \tag{5}$$

where: n: order, m:repetition, ρ and θ are respectively the radius and the angle of treated point of the function.

$$\beta_{n,m,k} = \frac{(-1)^{(n-k)/2} . (n+k)!}{(\frac{n-k}{2})! (\frac{k+m}{2})! (\frac{k-m}{2})!}$$ is a term whose

calculation depends neither on the image $f(x_j, y_i)$ nor of its co-ordinates (x_j, y_i) and $X_{m,k}$ is the general term which we calculate only once for all the repetitions.

Thus, the equation **(5)** reduces the computing of the Zernike moments of any image to the computing of a linear combination of these two last terms.

3 Zernike moments for face detection :

On consulting various work on the application of Zernike moments, we noticed that this form of representation was never used for the target detection even when the context of work presented required this operation. Thus, to localize the face, Haddadnia et al. [9] and Shahpour et al. [10] use in their works on the face recognition, a sequence of operations : segmentation, localization of related elements, approximation by an ellipse (representing the general shape of the face) and thresholding. Atsushi [11], in a similar work, uses a method based on the localization of space between eyebrows with ring frequency filter. In works concerning the analyses of images containing other objects than face by the Zernike moments the same observation is made. Rosenberger et al. [12], for example, used a segmentation to localize objects which they describe by Zernike moments.

However, the definition and the formulation of the Zernike moments as being parameters able to contain geometrical information of a two-dimensional function and to compress them in a

vector with reduced length make it possible to claim with their use in purpose of target image detection. Indeed, the geometrical moments are not abstract parameters. Each one of them have a significance related to the statistical characteristics of the bi-dimensional function which they represent such as the surface, the total mass center, the mass centers on horizontal and vertical directions, horizontal and vertical symmetry, ...etc. Thus, a face by its particular shape and its contents geometrically rich by the details of the elements which it contains (eyes, mouth, eyebrows...) could have certain preponderance on the parameters of the Zernike vector representing an image which contains it. This observation encouraged us to build a method of face detection based on the use of Zernike moments vectors as input to a neural network.

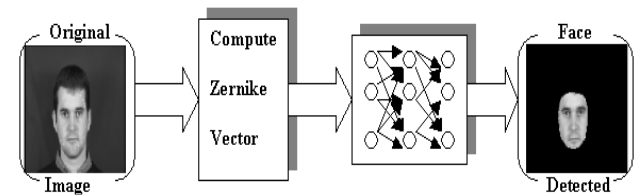Fig. 1 gives the diagram block of the detection system we propose.

Figure 1: *General diagram of the system detection*

The operation of face detection is thus done in two steps:

- During the first step, an image is presented to an algorithm which extracts representative Zernike vector.
- At the second phase, a back-propagation neural network, beforehand trained, receives on its input layer the Zernike moments vector. Then the neural network gives on its output layer a set of points representing the probable contour of the face contained in the original image.

The neural network is used to extract statistical information contained in the Zernike moments and in there interactions which are closely related to the area of the required face.

It should be notified here, that we make no assumption on the probable shape of the face subject to detection and no pre-processing operation is required for the image processed.

It is clear that the implementation of our method is mainly based on training phase which we summarize here in four stages:

- Computation of the vectors of Zernike moments for all the images (**N**) in the work database.
- Construction of the training database by randomly pulling up **M** images from the work database (**M<<N**) and their corresponding Zernike moments vectors **Zi**.
- Manual delimitation of the face area in each image of the training database by a set of points representing the contour **Ci** of each treated face.
- Training of the neural network on the set of **M** couples (**Zi**,**Ci**).

To test and measure the performances of the network obtained after training operation, we proceed, according to Fig. 1, on the hole (**N-M**) images remaining in the work database.

4 Experimental results :

In order to check the validity of our proposed method experimental studies were carried out on the XM2VTS images database [13]. It contains **4** recordings of **295** subjects taken over a period of 4 months with rotating head shot in vertical and horizontal directions. Images are **colour** and in **ppm** format.

In our experiences we first brought some transformations to the original images like the change to **gif** format (more compressed) and the use of luminance information only (gray scale images) to compute the Zernike moments.

To obtain the training database we take randomly **15** images of different people, each one with **3** different recordings, so that gives us **45** couples (**Zi**,**Ci**) examples for training the neural network.

To have a precise and rather general idea on the performances of the method, we carried out the construction of **40** training databases always by random taking of the examples. For each database, the network was trained then tested on the whole of the remaining images. For each test, we compute the rate of good detection pixels: it is the ratio of the number of pixels of the face which are correctly detected on the total number of pixels of the face.

To understand the relation between this rate and the observation we present on Fig. 2 **3** examples of face detection at various rates.
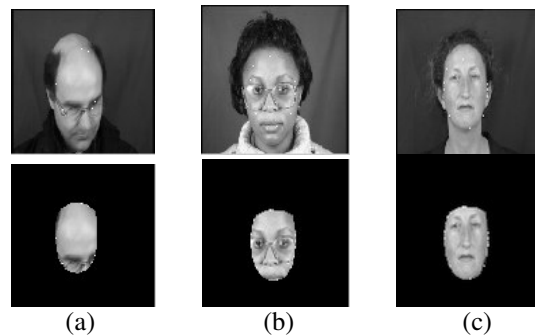

(a)   (b)   (c)

Figure 2: Examples of face detection at different good detection rates. Top: original image Bottom: pixels belonging to face surrounded by contour points.
(a): 41%, (b): 83% and (c): 100%

Our experiences aimed at the study of the behavior of the method with respect to the training database, the Zernike vectors parameters m and n and the complexity of the neural network.

In first, we present on Fig. 3 some general results with examples of good detected faces from the working database. Images were chosen to show variability in faces colour, pose, position and gender.
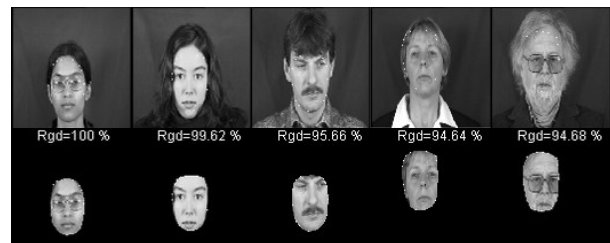

Figure 3: Examples of face detection Top : original image. Bottom : face detected.(Rgd: Rate of Good detection).

4.1 Training database influence :

First we wanted to know the influence that training database has on the quality of detection, especially when the choice of the examples is done randomly. Fig. 4 gives the results of tests validation for each of the 40 training databases. This tests were carried out on all the databases sequentially with the same parameters of Zernike vectors (order **m** equal to **10** and repetition **n** equal to **5**) as well as the same parameters of network (**10** neurons on hidden layer and **60** neurons on output layer) and this for three successive tests for each database. On Fig. 4.a we give the average of good detection on all the images of the validation database according to the training

on each one of the **40** databases. The general form shows that the quality of detection is subject to variations up to 8% of difference relating to the representativeness of the training database compared to the work database in entirely. The low values of the standard deviation given on Fig. 3.b show a generalization of the quality of detection for all the images. We obtain an average of **92.33 %** and **10.03 %**, according to the fourteen databases.

In the same way, we can notice that the variation of the standard deviation is inversely proportional to the average of good detection what shows that when the training database is rather representative, the most of faces are correctly detected.
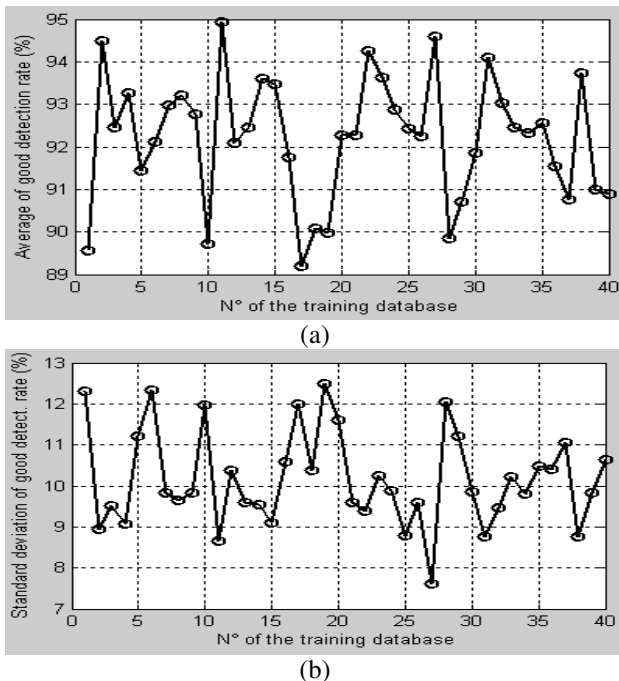

(a)

(b)

Figure 4: Good detection variations related to the training database. (a) Average (b) Standard deviation

4.2 Zernike parameters influence :

We also wanted to see the variation effect of parameters **n** and **m** on the good detection rate. These parameters have a direct influence on the complexity of the neural network and computing time of the algorithm in the sense that increasing **m**, **n** or the two increases the Zernike moments vector dimension which controls the dimension of the neural network input layer.

On Fig. 5 we give the variation curves for the average and the standard deviation of good detection rate according to the order **n** which goes

from **5** to **23** with a step of **2** and with **m=n-3** and a hidden layer with ten neurons. The average curve, computed for the ten neural networks obtained by training on the ten first databases, shows an oscillation in the values for different couples (**n,m**) but the general tendency is a decreasing due to the increasing of the complexity of the neural network. The standard deviation increases considerably with the increasing of the values of **m** and **n** which thus indicates the degradation of the measure generalization. According to average and standard deviation we obtain best results with **n=9** and **m=6**.
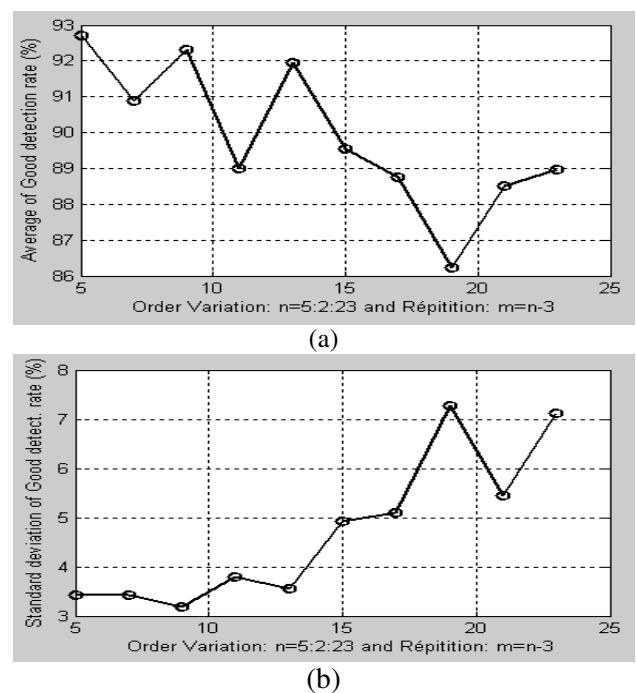

(a)

(b)

Figure 5: Average (a) and Standard deviation (b) of good detection for **n**=5,7,..., 23 and **m=n**-3

However, we found that the choice of **n** and **m** can not be dissociated from the choice of the training database in its diversity and its size and from the number of neurons in the hidden layer

4.3 Neural network complexity influence :

The neural network being the last element in the chain of detection system, we wanted to study the influence of the number of neurons in the hidden layer on the quality of detection. So we trained five neural networks with a variable Number of Neurons in the Hidden Layer (NNHL).

In Table 1 we give the results obtained in terms of average and standard deviation (Std) of the good detection on the first 10 training databases. Neural

networks with 10 and 15 neurons allow obtaining better average results. Beyond this value of NNHL, the complexity of the network decreases his ability to converge for most of the training databases. However, the best individually result obtained (**95.29 %**) was with NNHL equal to **25** on the tenth training database.

It should be also noticed that the average of detections remain very close since the total variation does not exceed the **1%** but the individual variation is about **4.87 %**.

Table 1 : Good detection according to NNHL

NNHL	5	10	15	20	25
Mean %	**92,32**	**92,87**	**92,72**	**92,33**	**92,55**
Std %	**01,30**	**01,33**	**01,34**	**01,64**	**01,30**

5 Conclusion :

We presented in this communication a new approach for face detection in an image. This method uses a neural network trained on Zernike moments vectors to localize and delimit the area supposed containing a face. The study of its performances was carried out on XM2VTS database through tests concerning the various parameters of the Zernike formulation and the neural network like the training database, the order **m** and repetition **n** parameters and the neural network complexity. We have shown the importance of the choice of the training database to improve the quality of detection. We have also shown that a judicious choice of **m** and **n** have to be done to ensure a high performances with a low complexity of the detection procedure.

Improvements on the judicious choice of the training database dimension and contents and compromise between m, n and NNHL can constitute the future work to be made to enhance performances of the method presented. This method can also be extended to localize face parts like eyes, mouth, nose, ... in images and video.

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