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Object Recognition using Image Processing

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Abstract: This paper contains an advanced new approach regarding image processing for model recognition. The application object is given by the following fields: face recognition and fingerprint recognition. For each identification model of recognition accuracy algorithms were set based on advanced analysis techniques, such as principal components analysis and independent component analysis. The improved version of this algorithm for face and fingerprint image detection was developed by using the independent component analysis (ICA) techniques. This new algorithm improved the rate of image recognition by using the information obtained from the evaluation of the scatter matrix with an ICA signature.

Keywords: ICA, BSS, Pattern recognition, Face recognition, fingerprint image detection.

1. INTRODUCTION

Image processing is a field of artificial intelligence that deals with the representation, reconstruction, classification, recognition and analysis of images using computer assisted technology.

The majority of the artificial vision algorithms need the use of image processing algorithms.
Examples of methods:

- Image enhancement - by transforming images: enhancing hidden/ obscure details, interest features
- Compression (compact representation of images/ transmission sequence/ storage)
- Restauration (elimination of known/ moldable degradation elements)
- Feature extraction (locating certain templates - for example: muscles, corners, complex structures - objects)

Image processing and analysis emerged and developed thanks to the idea and the need to replace the human observer with a device that would process data in a similar way to the human brain. The image processing process developed thanks to the emergence of some innovative ideas, as in the case of non-visible images (acoustic images, ultrasound, radar).

The modern digital technology made possible the processing of multi-dimensional signals using systems that can start from simple digital circuits spanning to advanced parallel calculus systems. The purpose of this processing can be distributed by three categories:

• Image processing: input image → output image;
• Image analysis: input image → output measurements;
• Image interpretation: input image → description of high level output

Image processing: both input and output (the result) are images. Applications: image transmission systems (with noise removal and data compacting techniques), under-exposed or unclear image enhancement (with contrast enhancement techniques), drastic image modification (illumination change, contour modification of some objects), the creating of a new image from a set of existing images (example: in medicine, the obtaining of the representation of some internal organs from X-ray images or from scintigraphic images).

The recognition of shapes in images: the production of either description of the input image or the assignment of the image to a particular class. Applications: correspondence sorting system (detects and identifies the digits in the postal code written on the envelope), medical diagnostic system (detects certain anomalies on X-rays or other medical images), etc.

It is considered representation of an image a pixel (integers) bi-dimensional picture. The value of each pixel describes the brightness level or its color. In the simplest of cases, that of binary images, a single bit is used for the representing of each pixel. As for the images having shades of grey, the value of each pixel represents its brightness.

The most common format for these images has as its starting point the representation of pixels in 8 bytes. Thus, the possible value range is 0…255, 0 encoding the color black and 255 encoding the color white, and the intermediary values represent shades (levels) of grey. As for color images, different color systems may be used (RGB, HSI, CMY etc.).

In mathematical modeling of the shape recognition problem there are theoretical approaches as well that elude any logical order. For example, the approach of recognition by statistic mathematical methods excludes the structural inclusion of the shapes in objects (with complex shapes) and the objects in images (containing several objects). A significant example is the statistic recognition method of images/ objects based on their chromatic content.

2. DESCRIPTION OF THE ALGORITHMS

2.1 The algorithm for Image Processing based on the Principal Component Analysis (PCA)

Usually, the databases used in the experiments of face recognition contain images of very high size. Such a "waste" of resources, valid also in the case of vocal signals or other natural images, leads to a significant robustness which allows the correct reception of the information transmitted, even if it is affected by noise, it is distorted or it is incomplete. On the other hand, the high size complicates significantly the practical implementation of the various processing techniques, they increase the calculation volume and, moreover, they need the existence of a large number of images in the data base in which they are operated (if the original images are seen as points in a multidimensional space, the bigger the dimension of the space is, the higher the of points is that is necessary in order to ensure a better "coverage" of the entire space for the purpose of ensuring an adequate approximation of the real distribution density of all the points representing valid images of human faces). In this context, the compression techniques prove to be useful as they are used to reduce the dimension of the original data by maintaining the inevitable loss of information as less as possible.
One of the most popular methods of compression belonging to the second class, called the Principal Component Analysis- PCA or the Karhunen-Loeve theorem [4].

The "raw material" is constituted by the ensemble of images available in the data base formed of real value matrices (or possibly binary). Each such matrix, supposedly of dimension (MxN), is firstly transformed in a vector of the same length, by concatenating the corresponding columns.

The processing algorithm contains the following steps:
a) calculate the average value if the images that form the engagement set (assumed to have K photographs, $I_j,\ j=\overline{1..K}$)

$$\bar{I}=\frac{\sum_{j=1}^{K} I_j}{K} \quad (1)$$

and the original images are "centered" (they are reduced to a null average value):

$$I_j^{center}=I_j-\bar{I} \quad (2)$$

b) calculate the so called scatter matrix (S) which represents the approximation of the co-variance matrix of the images in the database (the approximation is all the better as more images are available).

$$S=\frac{1}{K}A*A^T \quad (3)$$

where the matrix A has on its columns a centered image from (2):

$$A=\left[I_1^{center} I_2^{center} \ldots I_k^{center}\right] \quad (4)$$

The matrix S is symmetric and has the dimensions (M*N)x(M*N).

c) calculate the eigen values and the vectors of the matrix S (3) (the eigen vectors of the matrix S in case of working with images representing face is called Eigenfaces).

Notes: i) a short-cut may be used that reduces the volume of calculations: calculate the eigen values and the vectors of the matrix AT A and then use the relation between these two last ones and the eigen vectors of matrix S; ii) the eigen values of matrix S are always positive because S is real and symmetric [4].

d) the eigen values of matrix S are ordered in descending order. Draw a graph that conveys the loss of information in relation to the compression factor. The previous graph allows for the assessment of the number of eigen values and vectors that are considered significant (namely those that preserve the largest part of the energy of the original images).

e) project the original images (centered) in the space described by the eigen representative vectors (in number of 5-15% of the total number). In fact, the projects consists of processing the scalar product between each original image and a matrix having as columns only the eigen significant vectors. For each central image (centered) is obtained the projection:

$$W_j^T=I_j^{centerT}V_{PCA}$$
$$V_{PCA}=\left[E_1E_2 \ldots E_{N_{\max}}\right] \quad (5)$$

where V_{PCA} is the matrix of the eigen vectors, the Nmax is the maximum number of eigen vectors preserved, **E** are the eigen significant vectors and the **W** vectors may be seen as the "signatures" associated with the original images.

f) the classification of the test images propose firstly the determining of the "signature" of each image in relation with the subspace determined previously and the finding of that image in the engagement data base whose signature is closest to the signature of the test image. The assessment of the similarity between such pairs of images is achieved using a conveniently chosen metric. The usual option is the Euclidian distance, but other measures may be used such as the auto-correlation function, the cosine of the angle between two vectors or the Mahalanobis distance (The Euclidean distance, The Manhattan distance, The inter-correlation function, The cosine of the angle between vectors, The Mahalanobis distance).

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2.2 The new version of the algorithm for Image Processing based PCA and Independent Component Analysis (ICA)

The new version of this algorithm for face and fingerprint image detection was developed by using the independent component analysis techniques (FFR_PC_IC algorithm). This algorithm improved the rate of images recognition by using the information obtained from the evaluation of the scatter matrix (S) with a ICA signatures.

The steps of the improved algorithm are:

a) calculate the average value if the images that form the engagement set (assumed to have K photographs or fingerprint images) and the original images are "centered" (they are reduced to a null average value)
b) Calculate the so called scatter matrix (S) which represents the approximation of the co-variance matrix of the images in the database (the approximation is all the better as more images are available). The matrix S is symmetric and has the dimensions (M*N)x(M*N).
c) Calculate the eigen values and the vectors the matrix S.
d) The eigen values of matrix S are ordered in descending order.
e) Project the original images (centered) in the space described by the eigen representative vectors (in number of 5-15% of the total number). In fact, the projects consist of processing the scalar product between each original image and a matrix having as columns only the eigen significant vectors. For each central image (centered) is obtained the projection.
f) Determining of the "signature" of each image in relation with the subspace determined previously and for this matrix (Mic matrix) with all "signature images" we apply the estimating of the independent component analysis and establish the "independent signatures" of the Mic matrix. The"independent signatures" are obtained by applied the versions of the FastICA algorithm.
g) The classification of the test images propose finding of that image in the engagement database whose signature is closest to the signature of the test image (by using the independent signatures from previously step). The assessment of the similarity between such pairs of images is achieved using a conveniently chosen metric (The Euclidean distance, The Manhattan distance, The inter-correlation function, The cosine of the angle between vectors, The Mahalanobis distance).

2.2.1 Experimentally results

A. Results for Face Recognition

We use a database with 40 persons and for every person we have 10 face images (figure 1 - database images). The dimension for each images is 32x32 pixels and all the images will be transformed into the linear vector that become a column in the matrix with all images. For this database images was applied algorithm 1(the algorithm for Image Processing based on the Principal Component Analysis (PCA)) and algorithm 2 (The new version of the algorithm for Image Processing based PCA and Independent Component Analysis (ICA)).

Table 1. AbsMSE of versions of the Algorithm 1 and Algorithm 2 for experimental test A

Algorithm 1	**5% nr. of eigen values**	**10% nr. of eigen values**	**15% nr. of eigen values**
Corect Percentage of face recognition / Standard PCA algorithm	78.25%	84.25%	82.50%
Algorithm 2	**5% nr. of eigen values**	**10% nr. of eigen values**	**15% nr. of eigen values**
Corect Percentage of face recognition / **FFR_PC_IC algorithm and standard FastICA**	82.75%	85.50%	84.25%
Corect Percentage of face recognition / **FFR_PC_IC algorithm and Chebyshev FastICA**	84.25%	88.25%	86.75%

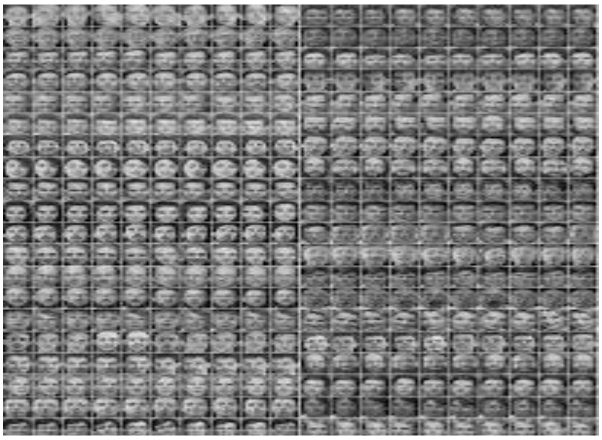

Figure 1: database images with 40 persons and for every person we have 10 face images

The results of the test regarding the appliance of the algorithm 1 based on PCA and of the algorithm 2 (FFR_PC_IC) based on PCA and ICA are given in table 1. We note that, for the proposed algorithms (FFR_PC_IC) based on PCA and ICA, the experimentally applications provide a good results (choosing 10% nr. of eigen values) compared with the Standard PCA algorithm. In case of the FFR_PC_IC algorithm and standard FastICAwe have corect percentage of face recognition equal with 85.50%; In case of the FFR_PC_IC algorithm and Chebyshev FastICA[1]we have corect percentage of face recognition equal with 88.25% and for the Standard PCA algorithm

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the corect percentage of face recognition is equal with 84.25%.

B. Results for Fingerprint Recognition

We use a database with 10 persons and for every person we have 10 fingerprint images (by using the fingerprint databases from FVC2002: the Second International Fingerprint Verification Competition, http://bias.csr.unibo.it/fvc2002/download.asp, figure 2). The dimension for each images is 32x32 pixels and all the images will be transformed into the linear vector that become a column in the matrix with all images. For this database images was applied algorithm 1 (the algorithm for Image Processing based on the Principal Component Analysis (PCA)) and algorithm 2 (The new version of the algorithm for Image Processing based PCA and Independent Component Analysis (ICA)).

Table 2. AbsMSE of versions of the Algorithm 1 and Algorithm 2 for experimental test B

Algorithm 1	**5% nr. of eigen values**	**10% nr. of eigen values**	**15% nr. of eigen values**
Corect Percentage of fingerprint recognition / Standard PCA algorithm	79.50%	84.75%	83.50%
Algorithm 2	**5% nr. of eigen values**	**10% nr. of eigen values**	**15% nr. of eigen values**
Corect Percentage of fingerprint recognition / **FFR_PC_IC algorithm and standard FastICA**	81.50%	87.25%	85.75%
Corect Percentage of fingerprint recognition / **FFR_PC_IC algorithm and Chebyshev FastICA**	83.25%	89.50%	88.50%

The results of the test regarding the appliance of the algorithm 1 based on PCA and of the algorithm 2 (FFR_PC_IC) based on PCA and ICA for fingerprint images are given in table 2. We note that, for the proposed algorithms (FFR_PC_IC) based on PCA and ICA, the experimentally applications provide a good results (choosing 10% nr. of eigen values) compared with the Standard PCA algorithm. In case of the FFR_PC_IC algorithm and standard FastICAwe have corect percentage of fingerprint recognition equal with 87.25%; In case of the FFR_PC_IC algorithm and Chebyshev FastICA [1] we have corect percentage of fingerprint recognition equal with 89.50% and for the Standard PCA algorithm the corect percentage of fingerprint recognition is equal with 84.75%.

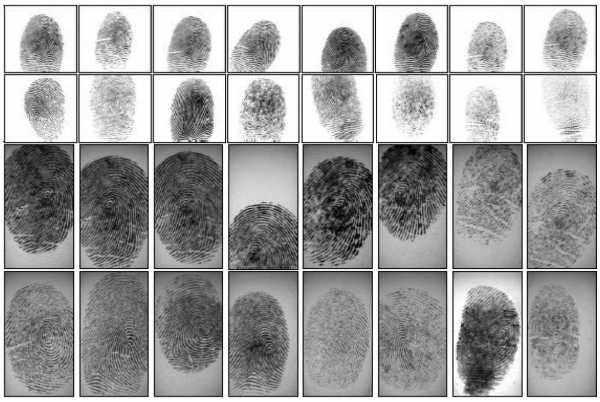

Figure 2: Sample images from the fingerprint databases FVC: the Second Int. Fingerprint Verification Competition,http://bias.csr.unibo.it/fvc2002/download.asp

3. CONCLUSIONS

The algorithm developed in this paper containes an advanced approach regarding image processing for model recognition. For each identification model of recognition accuracy algorithms were set based on advanced analysis techniques, such as principal components analysis and independent component analysis. The new version of this algorithm for face and fingerprint image detection was developed by using the independent component analysis techniques. This algorithm improved the rate of images recognition by using the information obtained from the evaluation of the scatter matrix with a ICA signatures in aplications like face recognition and fingerprint recognition.

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