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Designing algorithm for a new pattern descriptors set

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Abstract – The choice of an appropriate pattern description method is essential for the success of the following recognition or classification process. This paper shortly presents the designing methodology proposed by the authors for a new pattern descriptors set belonging to the complex moments family, which is invariant to the elementary geometric transformations and has increased noise robustness. Having as a starting point the usage of a real video image database, the experimental comparative results got in this case confirm new descriptors set proprieties.

Keywords: central moments, complex moments, Flusser moments, pattern recognition

I. INTRODUCTION

In order to be useful in pattern recognition process, the regions which resulted after input image segmentation must be represented in the suitable form. This form supposes concision, redundant information elimination and especially, hold back of the information that is necessary for interested pattern (objects) recognition. The process for acquisition of such interested region representation is knew in specialty literature as feature selection or feature description. The made description is in direct association with chosen data structure for representation, existing a strong dependence of concrete developed application.

The choice of suitable description modality is essential for success of the next pattern recognition process. Also, a fundamental principle that supervises the pattern descriptors construction is the invariance principle. This principle supposes that descriptors set to be invariant at different kind of linear and nonlinear transformations which are applied to interested pattern (it desired, especially, the invariance of used descriptors set at starting point, scaling, translation, reflection and rotation).

II. THE CONSTRUCTION METHODOLOGY OF A NEW DESCRIPTORS SET

The construction of a new pattern descriptors set proposed by author has as starting point the definition relation for *complex $(p+q)^{th}$-order moment* of a image function $f(x,y)$ with integrable property (Abu-Mostafa and Abo-Zaid, 1984) and which has the following form:

$$c_{pq} = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} (x+iy)^p (x-iy)^q f(x,y)\,dxdy. \quad (1)$$

It can demonstrate easily that:

$$c_{pq} = \sum_{k=0}^{p}\sum_{s=0}^{q}\binom{p}{k}\binom{q}{s}(-1)^{q-s} \cdot i^{p+q-k-s} m_{k+s,\,p+q-k-s}, \quad (2)$$

where m_{pq} is the *geometric $(p+q)^{th}$-order moment*.

In [1] it demonstrates the following important theorem: "*If are performed the following conditions:*

$$n \geq 1 \quad şi \quad \sum_{j=1}^{n} k_j (p_j - q_j) = 0, \quad k_j, p_j, q_j \in \mathbb{Z}^+,$$

then the product $I = \prod_{j=1}^{n} c_{p_j q_j}^{k_j}$ *is invariant at rotation*".

The principal disadvantage which apper associated with this construction mode of descriptors set $\{I_k\}$ is determinates by the fact this set is not invariant at others elementary geometrical transformations. A immediate solution it could be the realisation of the substitution $m_{pq} \rightarrow \eta_{pq}$ in (2):

$$c_{pq}^{(1)} = \sum_{k=0}^{p}\sum_{s=0}^{q}\binom{p}{k}\binom{q}{s}(-1)^{q-s} \cdot i^{p+q-k-s} \eta_{k+s,\,p+q-k-s}, \quad (3)$$

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Having as starting point the translation and scaling invariance of η_{pq} moments and the theorem presented above, it is easy to observe that the new descriptors set $\left\{I_k^{(1)}\right\}$ is invariant at elementary geometrical transformation (translation, scaling and rotation). Generally, this new set is complex and for gets real values it can hold back or its real part or its imaginary part.

For crystallize the final form of proposed invariant descriptors set it is necessary the introduction of a new type of *central $(p+q)^{th}$-order moment* and which has according [2] the following definition relation:

$$\lambda_{pq} = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty}(x - x_C + x_S)^p (y - y_C + y_S)^q \cdot f(x,y)\,dx\,dy, \tag{4}$$

where (x_C, y_C) are the coordinates of the interested pattern centroid and the shift factors x_s and y_s are chosen according [2]. Also, it can demonstrate that the new central moment can be normalised for getting its invariance at translation and scaling with help of next relation:

$$\xi_{pq} = \frac{\lambda_{pq}}{m_{00}^{\frac{p+q}{2}+1}}. \tag{5}$$

Palaniappan (1999) shows and demonstrates that through introduction of shift factors, the important *avantage* which thus results is the elimination of the standard central moments bugs in case of input symmetrical images use (related at a single axis or both), simultaneously with enhanced of sensibility at noisy factors action.

Evidently, by a similar reasoning with one which takes on getting of the third relation, it results a new set of complex central moments and whose form is:

$$c_{pq}^{(2)} = \sum_{k=0}^{p}\sum_{s=0}^{q}\binom{p}{k}\binom{q}{s}(-1)^{q-s} \cdot i^{p+q-k-s}\xi_{k+s,p+q-k-s}, \tag{6}$$

Therefore, the structure of new proposed pattern descriptors set it can rewrite over *the final form*:

$$\begin{cases} \zeta_1 = c_{11}^{(2)}; \\ \zeta_2 = c_{21}^{(2)} c_{12}^{(2)}; \\ \zeta_3 = \mathrm{Re}\left(c_{20}^{(2)} c_{12}^{(2)^2}\right); \\ \zeta_4 = \mathrm{Im}\left(c_{20}^{(2)} c_{12}^{(2)^2}\right); \\ \zeta_5 = \mathrm{Re}\left(c_{30}^{(2)} c_{12}^{(2)^3}\right); \\ \zeta_6 = \mathrm{Im}\left(c_{30}^{(2)} c_{12}^{(2)^3}\right); \\ \zeta_7 = c_{22}^{(2)}; \\ \zeta_8 = \mathrm{Re}\left(c_{31}^{(2)} c_{12}^{(2)^2}\right); \\ \zeta_9 = \mathrm{Im}\left(c_{31}^{(2)} c_{12}^{(2)^2}\right); \\ \zeta_{10} = \mathrm{Re}\left(c_{40}^{(2)} c_{12}^{(2)^4}\right); \\ \zeta_{11} = \mathrm{Im}\left(c_{40}^{(2)} c_{12}^{(2)^4}\right). \end{cases} \tag{7}$$

New pattern invariant descriptors set proposed by (7) has the following *four* important *properties*:

- ❑ it is invariant at elementary geometrical transformations (rotation, translation and scaling);
- ❑ it eliminates the standard central moments bugs in case of symmetrical images use;
- ❑ the robustness at noisly factors action is more increased;
- ❑ and not in finally, it forms a independent base of invariants (in sense of Flusser).

III. EXPERIMENTAL RESULTS

For demonstrate experimentally the properties of the new proposed descriptors set, it was used a database having as starting point *three* prototype-image, with 128×128 pixels, *halftone* and in *bmp* format.

Fig. 1 The prototype-image of database (top view)

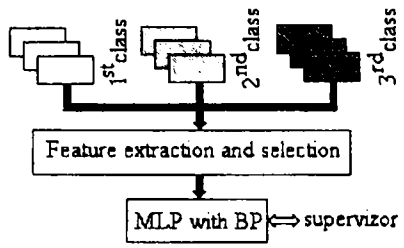
In a first step, based on prototype-image of each class, by scaling and rotation with different parameters was obtained 13 image/class. For recognition process was used a MLP neural network with BP.

The principal aspects which was followed are:

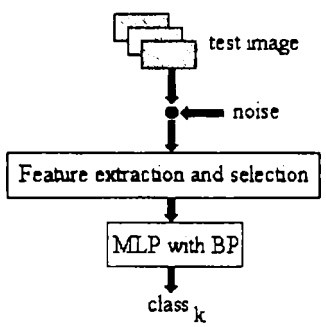
- ❑ *the test of proposed descriptors set invariance*
- ❑ *the test of behaviour of proposed descriptors set for different kind of input images symmetries*

❑ *the comparative test of proposed invariant descriptors set reported at reference descriptors set* (the descriptors set proposed by Flusser in [2]) *concerning noise robustness*

In this case, the database image was mixed with *salt and pepper* noise (specific for halftone image), the noise being inspected by his dispersion σ with an 10^{-2} increment in $[0, 0.1]$ range.



a) the training phase of MLP neural network



b) the noise robustness testing phase

Fig. 2 The noise robustness testing algorithm

σ=0.01 σ=0.05 σ=0.1

Fig. 3 An example of noised database image

Finally, it followed the graphic visualization and the interpretation (for two descriptors sets) of *the good recognition score* (GRS) or *the percent number* (%) *of good classified pattern* = *f*(σ) dependence.

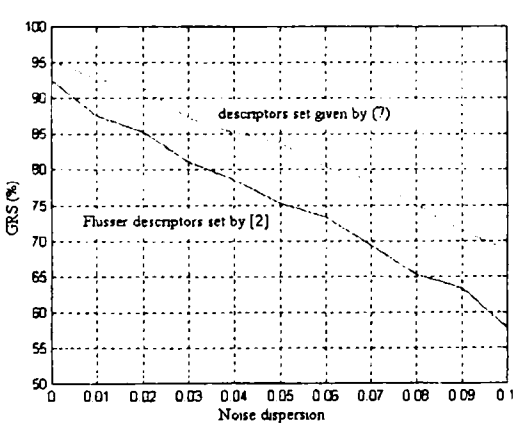


Fig. 4 The GRS=*f*(σ) dependence

❑ *the comparative test of new descriptors set reported at reference descriptors set in case of input image with variable (digital) resolution*

In this case, the initial database image was divided by 1:2 and 1:4 ratio and thus, was obtained the new structure of database used in the variable resolution testing phase.

128x128 pixels 64x64 pixels 32x32 pixels

Fig. 5 An example of the image resolution decrease effect

Also, it followed the graphic visualization and the interpretation (for two interested descriptors sets) of the GRS = *f*(*divider ratio*) dependence.

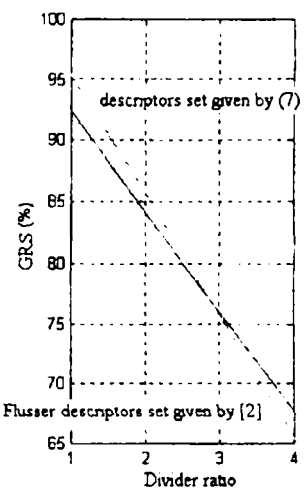


Fig. 6 The GRS=*f*(divider ratio) dependence

For more details about the experimental results obtained in this chapter, it can consult [2].

IV. CONCLUSIONS

The experimental results presented in this paper and with ones reported in [3], allow us to formulate the following *remarks*:

❑ the new descriptors set proposed by authors is invariant at elementary geometrical transformation;

❑ the standard central moments bugs for symmetrical input images are eliminated;

❑ the proposed descriptors set is more noise robust then reference descriptors set. Also, the topologies and the training or test phase performances of a neural network used for classification based on the new pattern descriptors set are comparable with ones getting in case of reference descriptors set;

❑ for a low decrease ratio of digital resolution, the classification performances are more increased reported at reference descriptors set and for high ratio this effect are inverted.

Therefore, *it justifies* the pattern recognition applications, which suppose the use of these new invariant descriptors set.

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