USING OF DISCRIMINATORY ANALYSIS TO PATTERN RECOGNITION OF TACTILE PATTERN

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Abstract

This paper described a new method of tactile pattern recognition. The method can be used a numeric regulator too. This method is based on the discriminatory analysis. The computation is going through all system of pattern classes. This corresponds to classical computing process, which is using in the discriminatory analysis. The Ivanovic deviation is used as discriminatory function. The m dimensional vector is impute and the method can classify into n groups of patterns. Pattern recognition can work at a real time.

1. Introduction

The discriminatory analysis is quickly and effectual method. It allows the complex problem solution with regard to the possible number of pattern classes and of pattern features. There are possible:

1. The computation is going through all system of pattern classes. This corresponds to classical computing process , which is using in the discriminatory analysis.
2. The computation is going through separate classes.

The author of this paper is interested by first alternate of solution. The Ivanovic deviation is used as discriminatory function.

2. The mathematical problem formulation

Let's have n of pattern classes marked $T_1,\ldots,T_i,\ldots,T_n$ and m of features marked $X_1,\ldots,X_j,\ldots,X_m$. The aim of problem classification is to insert unknown pattern to appropriate pattern classes.

Let's p_{ijl} be value of j features in l pattern in i class. Arithmetical average $\bar{x}_{ij}$ feature value of X_j of class T_i may be computed by following relation:

$$\bar{x}_{ij} = \frac{1}{P_i}\sum_{l=1}^{P_i} p_{ijl} \qquad (1)$$

P_i - number of pattern for class T_i.

We compute matrix $\underline{X} = \|\bar{x}_{ij}\|$ dimension n x m on the base of this dates. This matrix may be expressed by matrix table 1:

Tab. 1

Class / Feature	X_1	X_2	...	X_j	...	X_m
T_1	$\overline{x}_{11}$	$\overline{x}_{12}$	...	$\overline{x}_{1j}$	...	$\overline{x}_{1m}$
:	:	:		:		:
T_i	$\overline{x}_{i1}$	$\overline{x}_{i2}$	...	$\overline{x}_{ij}$	...	$\overline{x}_{im}$
:	:	:		:		:
T_n	$\overline{x}_{n1}$	$\overline{x}_{n2}$	...	$\overline{x}_{nj}$	...	$\overline{x}_{nm}$

The classes present m dimensional statistic sets in this problem. Every feature X_j an arithmetical average may be determined by

$$XC_j = \frac{1}{n}\sum_{i=1}^{n} \overline{x}_{ij} \tag{2}$$

The centre of gravity of system is as follows:

$$XC = (XC_1, \ldots, XC_m) \tag{3}$$

By formula (4) we compute dispersion σ^2 and standard deviation σ of all system for feature X_j:

$$\sigma_j^2 = \frac{1}{n-1}\sum_{i=1}^{n} (\overline{x}_{ij} - XC_j) \qquad j=1,\ldots,m \tag{4}$$

Then we compute symmetrical covariation matrix $\underline{W}$:

$$\underline{W} = \|w_{jk}\| \qquad j,k=1,\ldots,m \tag{5}$$

and symmetrical correlation matrix $\underline{R}$:

$$\underline{R} = \|r_{jk}\| \qquad j,k=1,\ldots,m \tag{6}$$

The coefficients of covariance matrix are defined by these forms:

$$\begin{aligned} w_{jk} &= \operatorname{cov} X_j X_k && j \neq k \\ w_{jj} &= \sigma_j^2 && j,k=1,\ldots,m \\ w_{jk} &= w_{kj} \end{aligned} \tag{7}$$

and the coefficients of correlation matrix are defined by these forms:

$$\begin{aligned} r_{jk} &= \frac{w_{jk}}{\sigma_j \cdot \sigma_k} \\ r_{jj} &= \frac{w_{jj}}{\sigma_j \cdot \sigma_j} && j,k=1,\ldots m \\ r_{jk} &= r_{kj} \end{aligned} \tag{8}$$

Let's $T_i = (x_{i1},...,x_{ij},...,x_{im})$ be the values of arithmetical averages of features for class T_i and $UNKN = (z_1,...,z_j,...,z_m)$ the values of unknown pattern.

Let's mark the values differences of j feature of i class and j feature of unknown patterns:

$$d_{ij} = \bar{x}_{ij} - z_j \qquad i=1,...,n\ ;\ j=1,...,m \qquad (9)$$

The deviation by observed of m features exists between class T_i and unknown pattern UNKN. This one presents the above expressed value of set of discrimination effects for all m features and in the discrimination analyse is called deviation and marked D.

These conditions have to fulfil a lot of conditions described in [1], [2]. There are conditions among them, concerning the specialities of deviation. Farther there are conditions, which have to be fulfilled in order to empty with existing problems and the problem solution should be definite.

A set of formulation of these deviations exists, but not all formulations comply with conditions described in [1], [2]. Ivanovic deviation formulated in [1] answers best this purpose. This one for unknown pattern of class T_i is defined by the formula:

$$D_i = \sum_{j=1}^{m} \frac{|d_{ij}|}{\sigma_j} \prod_{k=1}^{j-1}(1-r_{kj}) \qquad i=1,...,n\ ;\ j=1,...,m \qquad (10)$$

where

d_{ij} - is defined by relation (9)

σ_j- is standard deviation of features X_j

r_{kj} - coefficient of correlation between features X_k and X_j

This deviation fully describes no only linear, but even stochastic dependencies and non dependencies. The same it enables to compare individual classes with quantitatively incomparable functions, us features this case.

By pattern recognition of tactile image we can go out from idea, that a feature with greater variability can bring more information. Therefore this feature will be more to contribute to pattern recognition of an unknown pattern. Then it is possible to look at standard deviation as to eventual weight. Then the Ivanovic deviation can be defined by this formula:

$$D_i = \sum_{j=1}^{m} |d_{ij}| . \sigma_j . \prod_{k=1}^{j-1}(1-r_{kj}) \qquad i=1,...,n \qquad (11)$$

3. Pattern recognition system

There were chosen 8 classes (n=8) of tactile pattern: circles (i=1), right triangles (i=2), equilateral triangles (i=3) and isosceles triangles (i=4), pentagons (i=5), hexagons (i=6), squares (i=7) and rectangles (i=8). Eight features (m=8) were selected too: rectangularity (fig.1a), squarity, circularity (fig.1b), number of vertex, symmetry by axis x and y, incompatibility 1 (fig. 2a) and 2 (fig. 2b), which are different by form of computing of border.

Fig. 1a shows rectangularity and fig. 1b shows circularity. The rectangularity is defined as quotient of tactile image area and of describe rectangle area (in percents). The circularity is defined analogously. Fig. 2a and fig.2b show two possible way of computing of tactile image border length (thick outline).

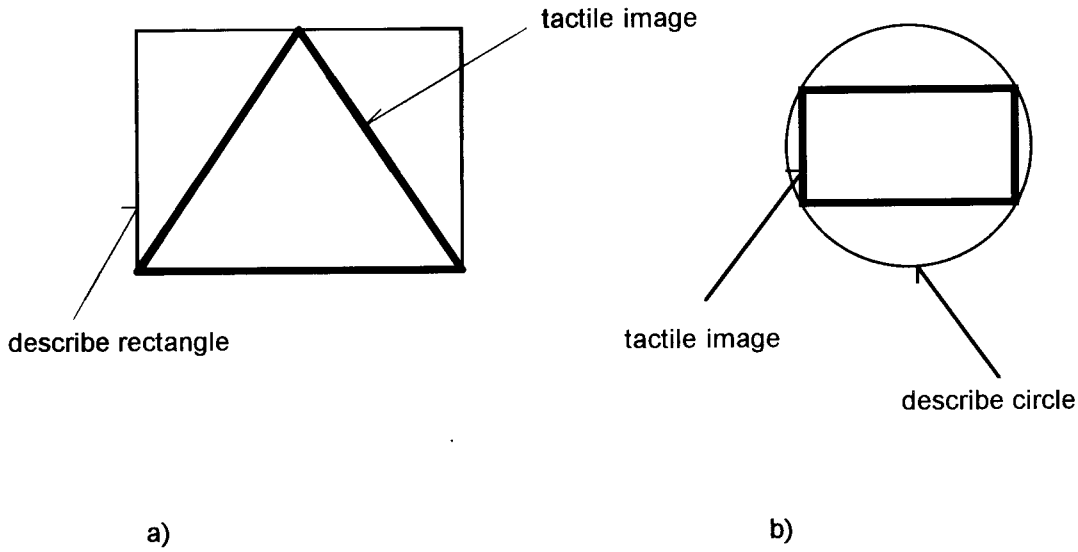

Fig. 1. Example of rectangularity and circularity

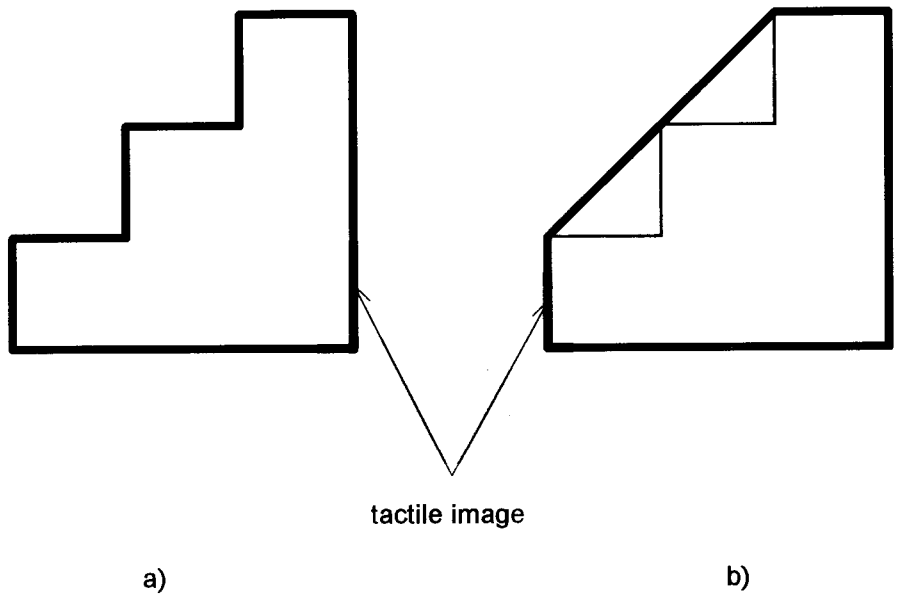

Fig. 2. Two methods for computing of border

Pattern recognition is resolved to two phases: learning and self recognition.

In the phase of learning we will advance to system know tactile images (patterns) and upon of its base we computing matrix of etalons $\underline{X}$ (tab. 1) and all other statistical parameters (correlation and covariantial matrixes dimension 8x8). These computations are realising once for always (if we don't to change classes of pattern).

In the phase of pattern recognition the tactile image vector should be computed from 8 features. In this way the tactile pattern is acquired. After the Ivanovic deviations of unknown pattern from etalon should be computed. By self classification the pattern is inserted into this class, for which the Ivanovic deviation is minimal.

4. Results of Pattern Recognition

System was learned by two data files DAT40 and DAT60. These two files differ by numbers of tactile images and by creating of some one. These data files were simulated on computer PC AT. The accuracy of classification was detected by an autotest. Images for autotest were selected accidentally. The results of classification are showed in Tab.2 for 100 tested tactile images and in Tab.3 for 500 tested images for both files of dates. The dates were simulated by computer PC AT too. The both alternates of computing of the Ivanovic deviation were used. The first alternate DA1 uses the Ivanovic deviation by formula (10) and the second alternate DA2 uses deviation by formula (11).

By using of the first alternate DA1 mainly triangles showed the differences. The accuracy of pattern recognition by isosceles and right triangles increased, but one decreased for equilateral triangles by using of files DAT60 against DAT40.

By using of the second alternate DA2 the total accuracy were increased for files DAT60 against DAT40. Big increase is for hexagons, again decrease is for rectangles. The appropriate choose have big effect for right pattern recognition. These dates have to represent very well appropriate class of patterns. This know result is to see from Tab.2 and Tab.3 too. We can say, that the second alternate DA2 is more successful as the alternate DA1.

Tab. 2

Class of pattern	Number of tested image	Success of pattern recognition in %			
		DA1		DA2	
		DAT40	DAT60	DAT40	DAT60
1	100	100	100	100	100
2	100	33	45	43	45
3	100	83	59	86	85
4	100	39	47	42	32
5	100	96	88	97	94
6	100	100	100	18	96
7	100	100	100	100	100
8	100	68	68	89	79

Tab.3

Class of pattern	Number of tested image	Success of pattern recognition in %			
		DA1		DA2	
		DAT40	DAT60	DAT40	DAT60
1	500	100	100	100	100
2	500	37	46	39	43
3	500	81	63	86	84
4	500	40	45	43	42
5	500	91	90	95	95
6	500	100	100	80	96
7	500	100	100	100	100
8	500	67	67	86	77

Classes of pattern:

1 circles
2 right triangles
3 equilateral triangles
4 isosceles triangles
5 pentagons
6 hexagons
7 squares
8 rectangles

5. Conclusion

The paper deals with the new methods for processing the tactile information and distinguishing the tactile images. These methods are based upon discriminatory analysis with using of Ivanovic deviation as discriminatory function.

Attained results show known declaration. Available selection of dates so that one represented very good appropriate class of images. This selection of dates have big influence upon learning of system and right pattern recognition.

The program does the most errors by classification of equilateral triangles which are inserted to class of isosceles triangles and again. The maximum (100 %) of right pattern recognition is obtained for circles, hexagons and squares.

The program for creating of features, computations and classification was written in turbopascal.

References

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