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RADON-ZERNIKE MOMENTS METHOD APPLIED IN POSTAL APPLICATION

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Summary: In this paper a new method of a handwritten characters recognition is introduced. The proposed algorithm is applied to classification of post mails on the basis of postal code information. In connection with this work the research was conducted with numeric characters used in real post code of mail pieces. Moreover, the article contains image processing, for instance, filtration of Radon transformation of the character. The main objective of this article is to use the Radon transform parameter space to obtain a set of moment features on basis of which postal code will be recognized.

Keywords: Character recognition, Radon transform, Zernike moments.

1. INTRODUCTION

The today's systems of automatic sorting of the post (Fig. 1) mainly use the OCR (Optical Character Recognition) mechanisms. In the present, recognizing of addresses (particularly written by hand) is still insufficient and needs to be improved.

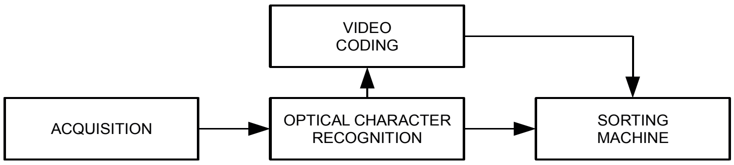

Fig. 1. The automatic sorting system – mail flow

The typical system of post mails sorting consists of the image acquisition unit, video coding unit and OCR unit. The image acquisition unit sends the mail piece image for interpretation. If the OCR unit is able to provide the sort of information required (this technology has 50% effectiveness for all mails [7]), it sends this data to the sorting system, otherwise the image of the mail pieces is sent to the video coding unit where the operator writes down the information about mail pieces. The main problem is that operators of the video coding unit have lower throughput and induce higher costs [7]. Therefore, the OCR module is improving, particularly in the field of recognition of the characters [16]. Although these satisfactory results were received for printed writing, the handwriting is still difficult to recognize. Taking into consideration the fact that manually described mail pieces make over 30% of the whole mainstream it is important to improve the possibility of segment recognizing the handwriting [20]. This paper presents the proposal of a system for recognition of handwritten characters for reading post code from mail pieces.

2. PROPOSED SYSTEM OVERVIEW

The process of character recognition (Fig. 2) can be divided into stages: preprocessing, Radon transform calculating, Zernike moment calculation, feature vector building, and character recognition stage. The first step of the image processing is preprocessing stage, where the colourful image mainly represented by 3 coefficients (red, green and blue) from the acquisition unit must be converted to the image with grey scale. The next step of processing of the image of postal code character is Radon transform. As a result, we obtain the parametric space where subsequent operations will be carried out. The main attention is drawn to the possibility of calculating the Zernike moments as features of the post mail code characters on the basis of the Radon parameter space. Application of Radon transform allows skipping several stages of preprocessing occurring in other publications, such as: binarization, filtration and normalization [16,19]. An additional advantage of this approach is that we do not need to realise the inverse Radon transform to calculate the image moments of the post mail code characters.

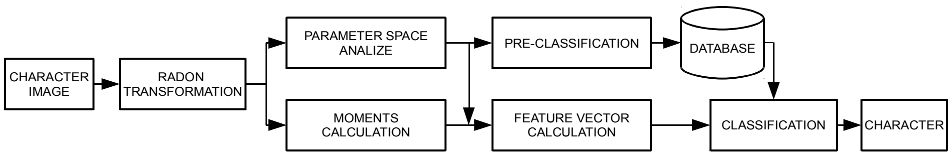

Fig. 2. The proposed method of character recognition

3. RADON TRANSFORMATION

In recent years the Radon transform has received much attention. This transform is able to transform two dimensional images with lines into a domain of possible line parameters, where each line in the image will give a peak positioned at the corresponding line parameters. This have lead to many line detection applications within image processing and computer vision. The Radon transformation is a fundamental tool which is used in various applications such as radar imaging, geophysical imaging, nondestructive testing and medical imaging [14,19]. The Radon transform computes projections of an image matrix along specified directions. A projection of a two-dimensional function $f(x, y)$ is a set of line integrals. The Radon function computes the line integrals from multiple sources along parallel paths, or beams, in a certain direction. The beams are spaced 1 pixel unit apart. To represent an image, the Radon function takes multiple, parallel-beam projections of the image from different angles by rotating the source around the centre of the image [2].

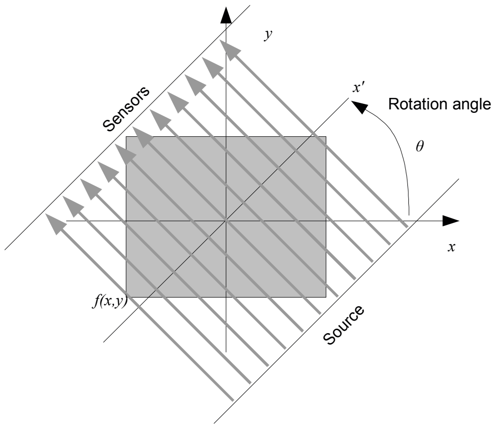

Fig. 3. Single projection at a specified rotation angle

Figure 3 shows a single projection at a specified rotation angle. The Radon transform is the projection of the image intensity along a radial line oriented at a specific angle. The radial coordinates are the values along the $x'-axis$, which is oriented at θ degrees counter clockwise from the $x'-axis$. The origin of both axes is the center pixel of the image.

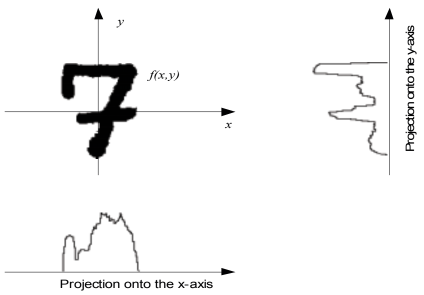

Fig. 4. Horizontal and vertical projections of a simple function

For example, the line integral of $f(x, y)$ in the vertical direction is the projection of $f(x, y)$ onto the $x'-axis$; the line integral in the horizontal direction is the projection of $f(x, y)$ onto the $y'-axis$. Figure 4 shows horizontal and vertical projections for a simple two-dimensional function.

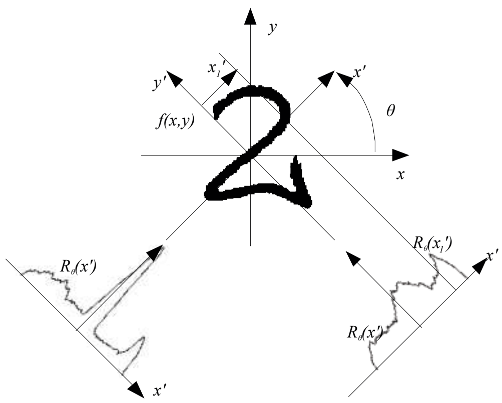

Fig. 5. Geometry of the Radon transform.

Projections can be computed along any angle θ by use of general equation of the Radon transformation [3,10]:

$$R_{\Theta}(x') = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x,y)\delta(x\cos\Theta + y\sin\Theta - x')dxdy \tag{1}$$

where $\delta(\cdot)$ is the delta function with value not equal zero only for argument equal 0, and:

$$x' = x\cos\Theta + y\sin\Theta \tag{2}$$

where x' is the perpendicular distance of the beam from the origin, and θ is the angle of incidence of the beams. The Fig. 5 illustrates the geometry of the Radon transformation. The Fig. 6 shows sample of accumulator data of Radon transformation.

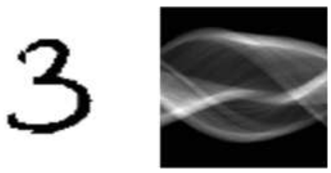

Fig. 6. Sample of accumulator data of Radon transformation.

The very strong property of the Radon transform is the ability to extract lines (curves in general) from very noise images. Radon transform has some interesting properties relating to the application of affine transformations. We can compute the Radon transform of any translated, rotated or scaled image, knowing the Radon transform of the original image and the parameters of the affine transformation applied to it. This is a very interesting property for symbol representation because it permits to distinguish between transformed objects, but we can also know if two objects are related by an affine transformation by analyzing their Radon transforms [15]. It is also possible to generalize the Radon transform in order to detect parameterized curves with non-linear behavior [6, 11,14].

4. ANALYSIS OF THE RADON PARAMETER SPACE

In the next stage of processing, Radon parameter space (accumulator) is analyzed to receive the vector of features of the character. To obtain one of the first part of vector's parameter we used the local peaks of the accumulator. Therefore, the initial accumulator data reduction is fulfilled by matching of local maximum operation. As a result of this stage, the amount of local peaks is limited as to the value of the threshold, which minimizes the intra-class variance and defined as a weighted sum of variances of the two classes, calculated basis on histogram for all accumulator cells. A second restraint is the distance between each of peak, which is determined on basis double value of mean thickness of the characters (keeping the unitary of scale transformation). Thus, on this stage we can notice that a series of characters are divided into some class because of the peaks amount. The Fig. 7 depicts a Radon transformation accumulators local peaks and their localization for sample characters.

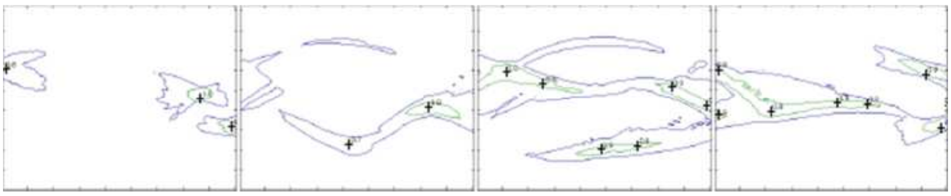

Fig. 7. The accumulator peaks and their localization for few digits

5. MOMENT CALCULATION STAGE

The group of moments calculated on the basis of radial functions are parameters determined on the basis of the Zernike polynomials. For the function of two real variables (such as an image) the polynomials can be written in the general form:

$$Z_{nm} = \frac{n+1}{\pi} \int_{0}^{2\pi} \int_{0}^{1} V_{nm}^{*}(r,\theta) f(r,\theta) dr d\theta \tag{3}$$

where V is the complex Zernike polynomial.

Figure 8 shows Zernike polynomials of various orders mn.

We considered the use of polynomial $P_{mn}(s)$ with coefficients A_{nmk} [8]:

$$P_{nm}(s) = \sum_{k=0}^{n} A_{nmk} s^{k} \tag{4}$$

by substituting the general form of radial polynomials we get:

$$\int_{0}^{1} \int_{0}^{2\pi} P_{mn}(s) e^{0im\phi} g(r,\theta) ds d\phi = \sum_{k=0}^{n} A_{nmk} H_{km} \tag{5}$$

where $g(r,\theta)$ is a parametric space of Radon transformation.

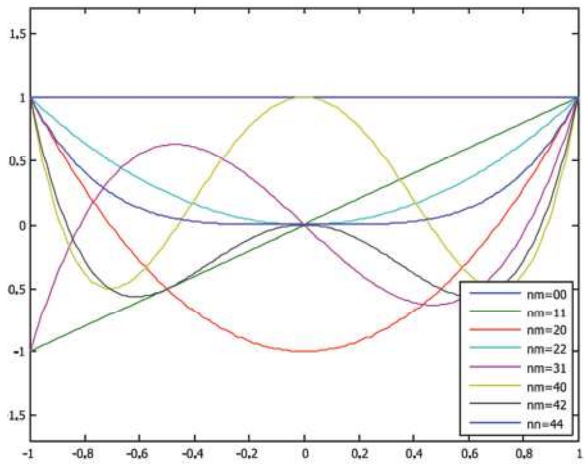

Fig. 8. Zernike polynomials of various orders *mn*.

We can determine the coefficients A_{nmk} in the form:

$$A_{nmk}=(-1)^{(n-k)/2}\frac{n+1}{2\pi^2}\frac{2}{k!}\frac{((n+k)/2)!}{((n-k)/2)!} \tag{6}$$

applying the [4]:

$$P_n(s)=\frac{n+1}{2\pi^2}\sum_{k=0}^{n}{}'(-1)^{\frac{n-k}{2}}\frac{\frac{n+k}{2}!}{k!\frac{n-k}{2}!}(2s)^k \tag{7}$$

we prove that the sum:

$$\sum_{k=0}^{n}{}'(-1)^{\frac{n-k}{2}}\frac{\frac{n+k}{2}!}{k!\frac{n-k}{2}!}(2s)^k \tag{8}$$

is the Chebyshew polynomial second kind order of *n* denote as $U(s)$ [8]. This will determine the complex Zernike moments which can be represented as:

$$Zc_{nm}=\frac{m+1}{2\pi}\int_0^{2\pi}\int_0^1 U_n(s)e^{-im\phi}g(r,\phi)dsd\phi \tag{9}$$

where

$$|m|\le n,\ \frac{n-|m|}{2}\in N\ . \tag{10}$$

Defined in this way, moment values allow us to formulate the feature vector of the postal code character consisting of modules of the Chebyshew polynomials Zc_{mn}. For each character feature vector consist of 8 values, defined as:

$$FV_{Mcz}=\{Mcz_{00},Mcz_{11}Mcz_{20}Mcz_{22}Mcz_{31}Mcz_{33}Mcz_{40}Mcz_{42}\}\ . \tag{11}$$

In order to observe changes in the value of the feature vector of character postal code was rotated. The Fig. 9 shows change in the feature vector of the rotated character image (presented on Fig. 10).

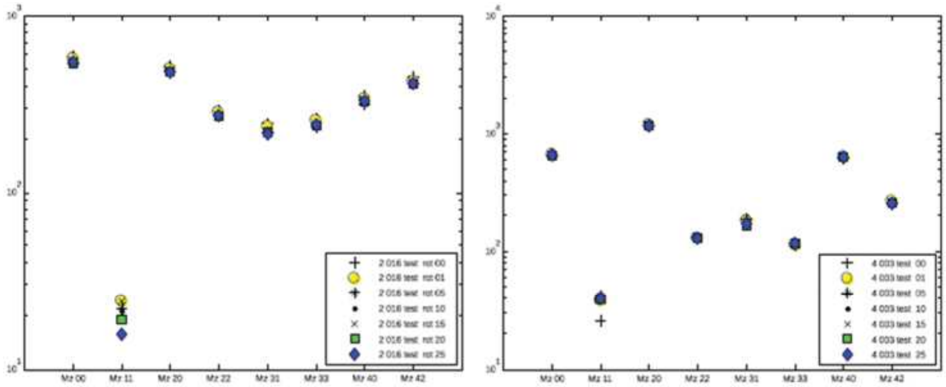

Fig. 9. The changes of *FV* depending from rotation of character image.

Additionally, beside the number of peaks *LP* from the Radon parameter space analysis stage, vector contains code of known character *ZN* as a Unicode [17]. After all, the feature vector consists of values $FV = \{ZN, LP, FV_{Mcz}\}$ for each character from training set.

Fig. 10. Sample of rotated digits form postal codes.

6. MODULE OF THE PRE-CLASSIFICATION

The aim of the preliminary classification is to reduce the number of possible candidates for an unknown character to a subset of the total character set. For this purpose, the selected domain is categorized into six groups with number of local maximum. It is worth mentioning that, after applying the preliminary classification, the number of wrongly classified characters was decreased. The analysis of the initial classification groups does not allow indicating the clear membership rules classes of character but rather may show their geometrical features. The preliminary classification is based on the amount of local maximum calculation in the Radon parameter space analysis stage.

7. CHARACTER CLASSIFICATION STAGE

The classification in the recognition module compared features from the pattern to model features sets obtained during the learning process. Based on the feature vector *FV* recognition, the classification attempts to identify the character based on the calculation of Euclidean distance between the features of the character and of the character models [1,18]. The distance function is given by:

$$D\left(PR,CR\right)=\sum_{j=1}^{N}\left[FV_B\left(j\right)-FV_R\left(j\right)\right]^2 \tag{12}$$

where:

- PR – is the predefined character,
- CR – is the character to be recognized,
- FV_B – is the feature vector of the predefined character,
- FV_R – is the feature vector of the character to be recognized,
- N – is the number of features.

The minimum distance D between unknown character feature and predefined class of the characters is the criterion choice [1].

8. EXPERIMENTS RESULTS

For evaluation experiments, we extracted some digit data from various paper documents from different sources e.g. mail pieces post code, bank cheque, etc. In total, the training datasets contain the digit patterns of above 200 writers. Our database include 1440 different digits patterns for training set and 600 digits for testing set. Comparing the results for handwritten character with other researches is a difficult task because there are differences in experimental methodology, experimental settings and handwriting database. In [12] authors presented a handwritten character recognition system with modified quadratic discriminant function, for which they recorded recognition rate of above 98%. Work [9] employed Hidden Markov Models for digits recognition. They obtained a recognition rate of 87%. The method described in [1] using Normalized Fourier Descriptors for character recognition obtained a recognition rate above 96%. Bellili using the MLP-SVM achieves a recognition rate of 98% for real mail zip code digits recognition task [5]. For comparison, proposed in this article method (Radon-Zernike) reaches recognition rate above 94% (see Tab. 1). Learning to recognition rate is the ratio of the number of learning characters to the number of testing characters. The results were compared with the methods Zernike-Image and Radon Profil [13].

Table 1. Character recognition rate for various testing set size.

	Learning to testing ratio				
	30	25	20	15	10
Method	Character recognition rate [%]				
Radon-Zernike	91,3	92,1	93,5	94,1	94,6
Zernike-Image	90,5	91,7	92,7	94,2	94,5
Radon-Profil	89,3	90,7	91,2	93,7	93,9

The Table 2 below shows the moment calculation time for different reference methods.

Table 2. The moment calculation time for different methods.

Image size (nxn)	Zernike moments	Radon-Zernike
64	0,231	0,535
96	0,524	0,783
128	0,936	1,044
160	1,461	1,316
192	2,110	1,573
224	2,874	1,841
256	3,770	2,112

9. CONCLUSIONS AND FUTURE WORK

Selecting the features for character recognition can be problematic. Moreover, the fact that the mail pieces have different sizes, shapes, layouts, etc., makes this process more complicated. The paper describes often used character image processing such as Radon transformation calculating. The main objective of this article is to use the Radon transform parameter space to obtain a set of moment features on basis of which postal code will be recognized. The presented method is less computationally complex for larger images (Tab. 2). For the future work, presented method will be upgraded to remaining all alphanumeric signs and special signs often placed on regular post mails.

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ZASTOSOWANIE MOMENTÓW RADONA-ZERNIKE DO APLIKACJI POCZTOWYCH

Streszczenie

W artykule przedstawiono nowe rozwiązanie zadania rozpoznawania znaków pisanych ręcznie dla zastosowań pocztowych. Zaproponowano algorytm klasyfikacji przesyłek pocztowych działający na podstawie informacji zawartej w zapisie kodu pocztowego. Główny nacisk położono na wykorzystanie transformaty Radona i momentów Zernike do uzyskania zbioru cech, na podstawie, których rozpoznawano kod pocztowy. Otrzymane wyniki eksperymentów pozwoliły wykazać skuteczność proponowanej metody.

Słowa kluczowe: rozpoznawanie znaków, transformata Radona, momenty Zernike