INVARIANT RADON-MOMENT DESCRIPTOR FOR POSTAL APPLICATIONS

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Abstract. In this article a new solution of handwritten digits recognition system for postal applications is presented. Moreover, in this paper, a new approach of handwritten characters recognition was presented. The implemented algorithm is applied to recognition of postal items on the basis of postcode information. In connection with this article the research was carried with all digit characters used in authentic zip code of various mail pieces. Additionally, the paper contains some preliminary image processing for example normalization of the character. The main objective of this article is to use the Radon Transformation and other moments values to obtain an invariant set of character image features, on basis of which postal code will be classified. The reported experiments results prove the effectiveness of the proposed method. Furthermore, causes of errors as well as possible improvement of recognition results will be presented.

1 Introduction

Currently used systems of automatic post mails sorting very often use the OCR (Optical Character Recognition) mechanism. Currently the recognizing of address data elements (particularly written by hand) by the automatic systems is still unsatisfactory. The standard automatic post mail sorting system Fig.1 comprises of the image acquisition section, video-coding section and Optical Character Recognition module. Functioning of the system is the following, the image acquisition section transfers the postal code image to the recognition module (OCR) for processing. If the character recognition module is able to give address data information (this technology has about 50% effectiveness for all mailstream [7]), it sends address data (usually zip code) to the sorting system, any other way the mailpiece address image is transferred to the video-coding section, where the group of operators manually writes down the correct information about addresses area. It turns out, the main problem in this scenario is that the operators of the video coding section have very small throughput than an automatic recognition system and gen-
erate higher costs [7]. As a result, the automatic character recognition system is still improving, particularly in the field of interpretation of the manually written characters. Despite the fact that satisfactory results were received for printed writing, the manual writing is still difficult in the interpretation. Additionally, taking into account the fact that handwritten described post mail pieces represent 30% of the whole mail traffic, it is very important to ameliorate the recognition rate of module handwriting recognition. This work presents new proposal of an automatic system for recognition of manually written digits from mailpieces addresses. The main objective of this article is to use the Radon Transform parameter space to obtain a set of moment features. Most moment methods are based directly on the image. It is a new method based on the parameter space of Radon. This approach eliminates inverse Radon Transform to calculating the moments. In addition, the parametric space can be used for other purposes such as postal stamps value verification.

2 The proposed postcode recognition system

The algorithm of postcode character image processing can be divided into three phases: image character normalization, Radon Transformation calculating, feature moments calculating and feature vector building. The proposed algorithm is presented on Figure 2. The first phase of the character image transformation is the gray scale image normalization. Usually the colorful image is represented by three factors: Red, Green and Blue (RGB) from the acquisition stage and should be transformed to the gray scale image representation. The next step of character image processing is The Radon Transformation. The final stage of preprocessing is moment feature calculation basis on the Radon parameter space. The proposed method of character recognition was shown on Figure 3. Additionally, the presented solution can use the preliminary classification stage. The main objective of the preliminary classification stage is to reduce the amount of possible candidates for an unknown character, to a subset of the total character set. For this reason, the selected domain is divided into several different subgroups. The analysis of the elements belonging to different subgroups does not allow to show the bright membership rules classes of character, but rather can be shown their geometrical features. Furthermore, preliminary classification stage can be used to establish rejection of alphabetical character too. Based on the feature vector 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].

2.1 Character image normalization

Before the transformation the character image is normalized all its regions to a mean and variance. This processing is performed to delete the undesirable effects of sensor
noise and white level distortion. Additionally, the removing of salient points, executed later in proposed method, determined by the illumination variance in character image. For that reason, in order to achieve proper illumination and contrast invariance, character image is normalized [10]. Let \( I(x,y) \) indicates a gray value at the image pixel \((x,y)\), \( E \) and \( V \) be the approximated mean and illumination variance in the image \( I \), accordingly, and \( I_n(x,y) \) stand for the normalized gray level value at the image pixel \((x,y)\). Therefore, for all image pixels \( I \), the normalization process is determined as follows [3, 2]:

\[
I_n(x,y) = \begin{cases} \frac{E_0 + V_0 (I(x,y) - E)^2}{V} & \text{if } I(x,y) > T_n, \\ E_0 - \frac{V_0 (I(x,y) - E)^2}{V} & \text{otherwise}, \end{cases}
\]

(1)

here \( E_0 \) and \( V_0 \) are the proper mean and variance values, accordingly, \( E \) and \( V \) are the calculated mean and variance in the image, denoted by

\[
E = \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} I(x,y),
\]

(2)

\[
V = \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} (I(x,y) - E)^2,
\]

(3)

respectively. In this case, \( E_0 = 100 \), \( V_0 = 100 \) and \( T_n = 128 \). As a result of the operation of luminance levels normalization image \( I_n \) is obtained.

The character image obtained from the acquisition module has very often distorted in different ways, that include: scaling, translation and rotation. Therefore, the character normalization stage is applied for standardization size of the characters from acquisition phase. Character images there are translated, rotated and expanded or decreased. The standard solutions takes into account the normalization image coefficients and compute the new coordinates in the form of:

\[
[x',y',1] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ -t_i & -t_j & 1 \end{bmatrix} \times \begin{bmatrix} s_i & 0 & 0 \\ 0 & s_j & 0 \\ 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} \cos \theta & \sin \theta & 0 \\ -\sin \theta & \cos \theta & 0 \\ 0 & 0 & 1 \end{bmatrix}
\]

(4)

where: \( t_i, t_y \) is a center of gravity given by :

\[
t_i = \frac{\sum_i \sum_j i f(i,j)}{\sum_i \sum_j f(i,j)}, \quad t_j = \frac{\sum_i \sum_j j f(i,j)}{\sum_i \sum_j f(i,j)}
\]

(5)

This is the new coordinate system where the center equals to centre of the gravity of the character image. The new calculated value of the image rotation depends on the main axes of the image. The new value of scale factor is determined by mean value of variation of the image character. Therefore, the center of gravity of the image character is a good assumption point of the center of image as a effect of normalization phase.

### 2.2 Radon Transformation

Recently the Radon Transformation have received much more attention. This transformation is able to change two dimensional images with lines into a domain of possible line parameters, where each line in the transformed image will give a peak placed at the issuable line parameters. This has lead to many line detection applications [19]. The Radon Transformation is a basic tool which is used in miscellaneous applications such as radar imaging, geophysical imaging, nondestructive testing tool and medical imaging tool [20].

The Radon Transform calculates projections of an image matrix along strictly defined directions. A projection of a two-dimensional function \( f(x,y) \) is a set of line integrals along an input image. The Radon function calcu-
The Radon Transformation is the set of projection of the image intensity along a radial line rotated at a specific angle. In this way the new radial coordinates are the values along the \( x' \)-axis, which is oriented at \( \theta \) degrees counter clockwise from the \( x \)-axis. The center of both axes is the center pixel of the transformed image. Therefore, the line integral of \( f(x, y) \) in the vertical direction is the Radon function projection of \( f(x, y) \) onto the \( x \)-axis, whereas the line integral in the horizontal direction is the projection function of \( f(x, y) \) onto the \( y \)-axis.

So, the projections can be calculated along any specific angle \( \theta \), by use general form equation of the Radon Transformation [1, 4, 12]:

\[
R_\theta(x') = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} f(x, y) \delta(x \cos \theta + y \sin \theta - x') \, dx \, dy
\]  

where:

\[
\delta(x \cos \theta + y \sin \theta - x') \]

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

\[
x' = x \cos \theta + y \sin \theta
\]

\( x' \) is the simple perpendicular distance of the beam from the center and \( \theta \) is the angle of range of the beams.

One of the best properties of the Radon Transform is the ability to indicate lines (curves in general) from noisy images. Moreover, Radon Transformation has certain interesting properties referring to the application of affine image transformations. It can compute the Radon Transform of any translated, rotated or even scaled image. This is a very important property for symbol representation because it allows to discriminate between transformed objects, but it can also know if two objects are related by an affine transform by checking their Radon Transforms parameter space [20]. Moreover, it is also possible to generalize the Radon Transformation form for detect parameterized curves with non-linear behavior [19, 6].

### 2.3 Radon-moment calculation

The Radon Transformation \( g(s, \phi) \) can be defined as a set of lines parallel to the axis of \( t \) passing through the points where \( s \), along which are summed up in the image points. As defined transformation can be represented as follows:

\[
g(s, \phi) = \int f(s, t) \, ds
\]
Function (9) is also often referred to as a function of the projection satisfies the identity or sinogram:

\[ g(-s, \phi + \pi) = g(s, \phi) \]  \hspace{1cm} (10)

Implementing the functions of projection for all angles of \( \phi \) and points \( s \) in result the Radon Transform is obtained.

On the basis of the parameter space it is possible to determine the geometrical moments of the image.

Taking into account the general form of the normal moment \( \mu \) order of \( n \):

\[ \mu_n = \int_{-\infty}^{\infty} x^n dF(x) dx \]  \hspace{1cm} (11)

we can determine the moment of the normal \( H \) order of \( k \) along a straight \( s \) for a fixed angle \( \phi \), which can be written in the form:

\[ H_k(\phi) = \int_{-\infty}^{\infty} s^k g(s, \phi) ds \]  \hspace{1cm} (12)

where:

\[ g(s, \phi) = \int f(s, t) dt \]  \hspace{1cm} (13)

and

\[ s = x\cos\phi + y\sin\phi \]  \hspace{1cm} (14)

while

\[ s^k = (x\cos\phi + y\sin\phi)^k \]  \hspace{1cm} (15)

Modify (15) according:

\[ (a + b)^n = \sum_{k=0}^{n} \binom{n}{k} a^{n-k} b^k \]  \hspace{1cm} (16)

where for: \( a = x\cos\phi, b = y\sin\phi, n = k \) we get:

\[ s^k = \sum_{j=0}^{k} \binom{k}{j} y^{k-j} x^j \cos^j \phi \sin^{k-j} \phi \]  \hspace{1cm} (17)

The thus obtained dependence can be substituted into the (12), thereby obtaining:

\[ H_k(\phi) = \sum_{j=0}^{k} \binom{k}{j} \cos^j \phi \sin^{k-j} \phi \int_{-\infty}^{\infty} g(s, \phi) y^{k-j} x^j ds \]  \hspace{1cm} (18)

By changing the limits of integration

\[ \int_{-\infty}^{\infty} g(s, \phi) ds = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} f(x, y) dxdy \]  \hspace{1cm} (19)

We can lead to a form of:

\[ H_k(\phi) = \sum_{j=0}^{k} \binom{k}{j} [H_{j-k}^k(\phi)] \times \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} f(x, y) x^j y^{k-j} dxdy \]  \hspace{1cm} (20)

on the basis of which can be determined the geometric moments of the parametric Radon Transform [18]. In work [8] the authors demonstrated that the expression (20) is reversible, which in turn allows to determine the geometrical moments of the same image.

Determination of the moments value allows us to formulate the vector characteristics of the analyzed image character eg. central moments Hu [14] These values can be used to construct a feature vector of character.

For each image feature vector \( FV_{Mc} \) of the character set includes of eight central moments \( Mc \) bypassing steps \( p = 0, q = 1 \) and \( p = 1, q = 0 \) for which values are zero.

\[ F_{Mc} = \{Mc_{00}, Mc_{11}, Mc_{02}, Mc_{20}, Mc_{21}, Mc_{12}, Mc_{30}, Mc_{30}\} \]  \hspace{1cm} (21)

For Hu moments feature vector \( FV_{Mh} \) includes the first 8 values of invariants defined in the [14]:

\[ F_{Mh} = \{Mh_1, Mh_2, Mh_3, Mh_4, Mh_5, Mh_6, Mh_7, Mh_8\} \]  \hspace{1cm} (22)
In a similar way to obtain a feature vector consisting of a set of moments of the Radon Transform parameter space.

3 Experimental results

In this section are presented the results of classification experiments with the proposed method. The main aim of the experiment is to confirm the suitability of this method for character recognition and the demonstration of the invariance of the method due to the rotation of character image. Particularly for evaluation experiments, extracted some image of digit data from various paper documents from various sources e.g. mail items postal codes, bank checks, etc. The image character samples were scanned with 600dpi in color and stored in treset data collections [9] in the form of 24-bits (RGB) and 8-bits (grayscale) images. Important in the case of images with heterogeneous background to perform directional filtering. Next, the character image is normalized as in the second paragraph. Based on geometric and central moments, center of gravity and main axis angle can be achieved. Finally, the data sets include the digit patterns of above 150 writers. In such a way were collected about 1400 different image patterns for training and testing procedures.

Figure 5 shows the effect of rotation on the parameters of the feature vector $FV_{Mc}$ character image and the effect of rotation on the parameters of the same feature vector, but from Radon parameter space for digit 2.

Figure 6 shows the effect of rotation on the parameters of the feature vector $FV_{Mc}$ character image and the effect of rotation on the parameters of the same feature vector, but from Radon parameter space for digit 4.

For comparison Figure 7 shows the effect of rotation on the parameters of the feature vector $FV_{Mc}$ character image and the effect of rotation on the parameters of the same feature vector, but from Radon parameter space for digit 2.

Figure 8 shows the effect of rotation on the parameters of the feature vector $FV_{Mc}$ character image and the effect of rotation on the parameters of the same feature vector, but from Radon parameter space for digit 4.

The proposal system based on Radon-moment method generates a set of data, which can be used as features in building feature vector stage. For instance, when can be used input features from central moments features and Hu moments, as a result 8 values vector can be obtained. On the basis of the experiments obtained recognition rate 92% of correctly classified characters from zip code digits database. The best results were obtained for the Hu moments character feature vector using similarity measurement. The results obtained for testing 6 sets defined in
Fig. 6: Image and Radon parameter space feature vector ($FV_{Mc}$) for digit 4

Comparing obtained results for handwritten zip-code digits with other researches is a difficult task because are differences in experimental methodology, experimental setup and image database. In [13] the authors presented a handwritten character recognition method with modified quadratic discriminant function, they reported recognition rate of above 98%. On the other hand, in the article [11] using Hidden Markov Models for digits recognition. The authors obtained a recognition rate of 87%. However, in the paper [1], the authors using Normalized Fourier Descriptors for character recognition have achieved a recognition rate above 96%. Other solution [5] using the MLP-SVM allowed to reach 89% efficiency for mail zipcode characters recognition task. Despite the lower capacity of the method, presented solution it allows you to omit the pre-processing steps. The use of the Radon parameter space allows the use of several other methods of obtaining image character features as well as allows for invariance from the shift, rotation and change scale.

4 Summary

This work presents new approach to realise the optical character recognition system, specifically used in the recognition of post mail code. However, the area is well
known and explored, with many successful examples of both scientific and commercial implementation, but efficiency of automatic mail sorting systems is still imperfect. The author of this work hopes that this solution may be supportive for the previous works [15, 16, 17] and other approaches such as [1, 5, 13]. The most common optical character recognition methods are based on modified quadratic discriminant function, hidden Markov models, normalized Fourier descriptors or MLP-SVM techniques. In the article, the idea and implementation of use of the Radon Transformation and various moments values in the process of character recognition in postal applications were presented. In order to decimalize those procedures, in the first stage we prepared the pre-processing character image using gray scale and coordinate normalization. In the article, approach to the optical character recognition was presented and tested. In this method, the estimation of character features using was performed. After experiments concluded that moments features based on Radon Transformation were the most appropriate for character descriptor, respectively. The main advantages of the proposed method are: finding geometric relations of the parameter space and geometric moment calculation, invariance to background noise, low computational complexity, working with gray scale images. Disadvantages: low value of the rejections, need to use some pre-processing. In further work the author will include other moments theory and upgraded to all alphanumeric signs.

References


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