A New Approach for Object-Feature Extract and Recognition

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Abstract: A new approach for object recognition is presented in this paper. The algorithm is based on the theory fully described in a previous work. Experiments were carried out for chosen capital letters from twelve different font styles. A modification to the original idea is shown and applied to achieve better results of different letter recognition. The results are good and encourage to further work on other applications like handwritten script and geometrical-pattern recognition.

Key words: Object Features Extract; Classification; Recognition.

1. INTRODUCTION

Object recognition is a very difficult task [1]. Despite many efforts to solve this problem [2,3,4,5,6,7] there still are no perfect solutions. The aim of this work is a modification of algorithms described in [1, 3] to reduce the percentage of error in the process of classification. Presented experiments were carried out for separate capital letters of Latin alphabet as examples of simple objects. However, the possible applications of the theory are not limited to this particular case. There are experiments on recognizing entire words [8,9] and other kinds of geometrical shapes [10].

2. THEORETICAL ASPECTS

According to the method given in [1], examined object-features is described by the following rational function:

$$H(s)=\frac{P(s)}{Q(s)} \tag{1}$$

where *P(s)* and *Q(s)* are *n*-degree polynomials whose coefficients are described by the coordinates of the feature points . Then the following bilinear transformation is applied:

$$s = \frac{1 - p}{1 + p} \tag{2}$$

resulting in another rational function *H(p)*.

In the next step the coefficients of Taylor's series for *H(p)* are calculated and used to create Toeplitz matrices. Determinants of these matrices are formed to calculate minimal eigenvalues.

Taylor series:

$$T(p) = c_0 + c_1 p + c_2 p^2 + ... + c_n p^n + ... \tag{3}$$

where c_i for $i = 0, 1, 2, ..., n$:

$$c_i = \frac{1}{x_0^{\,i+1}} \begin{vmatrix} y_i & x_1 & x_2 & \dots & x_i \\ y_{i-1} & x_0 & x_1 & \dots & x_{i-1} \\ y_{i-2} & 0 & x_0 & \dots & x_{i-2} \\ y_{i-3} & 0 & 0 & \dots & \dots \\ \dots & \dots & \dots & \dots & x_1 \\ y_0 & 0 & 0 & \dots & x_0 \end{vmatrix} \tag{4}$$

Determinants of Toeplitz matrices are evaluated from coefficients of Taylor series:

$$D_i = \begin{vmatrix} c_0 & c_1 & c_2 & \dots & c_i \\ c_1 & c_0 & c_1 & \dots & c_{i-1} \\ c_2 & c_1 & c_0 & \dots & c_{i-2} \\ \dots & \dots & \dots & \dots & \dots \\ c_i & c_{i-1} & c_{i-2} & \dots & c_0 \end{vmatrix}, \quad i = 0, 1, 2, \dots, n \tag{5}$$

From the minimal eigenvalues $\lambda_{\min}\{D_i\} = \lambda_{\min_i} = \lambda = 0, 1, 2, \ldots, n$ the following feature vector is formed:

$$< \lambda_0, \lambda_1, \lambda_2, ..., \lambda_n > \tag{6}$$

This result is passed to classification algorithm.

3. MODIFICATION AND EXPERIMENTS

The modification to the algorithm is the bitmap image of the object. The first task is to choose the characteristic points. To accomplish this goal top and down views are evaluated. The view is a set of pixels belonging to character's contour and have extreme coordinate *y* for a given coordinate *x*.

As an example describing the shape of object, consider three capital letters viewed according to the algorithm (Fig. 1).

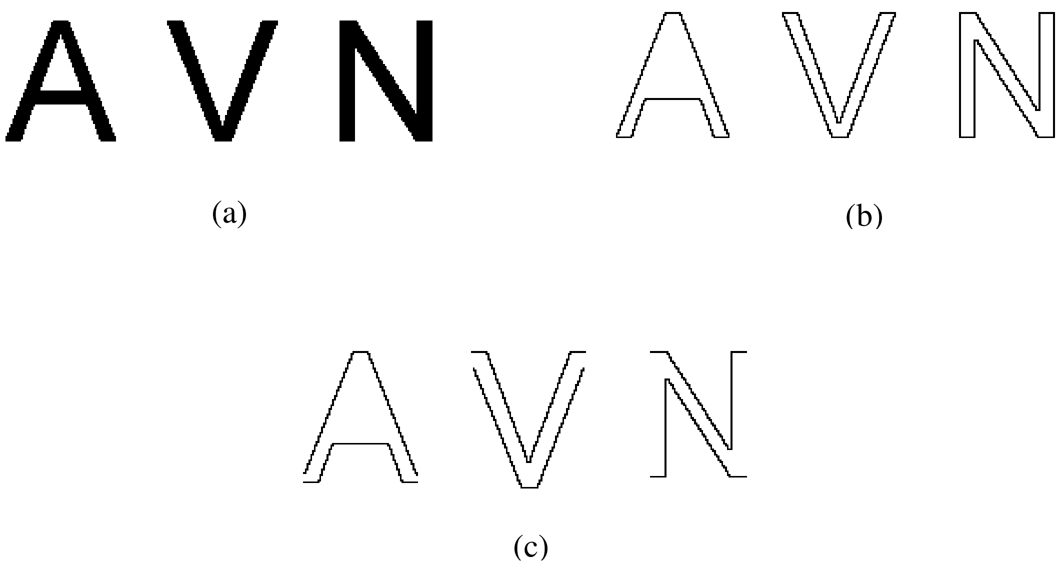
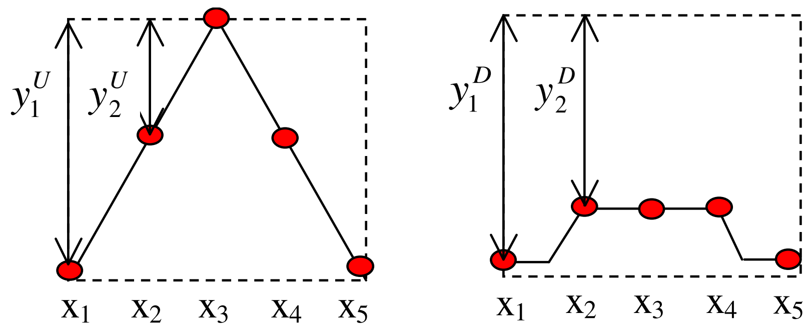


Fig. 1. Concept of views. (a) Hypothetical letters, (b) letters thinned to contour, (c) their top and down views

Next, after choosing characteristic points from views, the distances of these points from upper side of surrounding rectangle are calculated. The sequence formed from such values is a description of the view and is used to construct the rational function *H(s)*. In addition, *x* coordinates of projected points are included.



(a) (b)

Fig. 2. Projection of characteristic points describing the views. (a) shows letter A's top view, (b) shows letter A's down view

Figure 2 shows how the projection of characteristic points is done. For the upper view the result is the following vector:

$$< y_1^U, y_2^U, y_3^U, y_4^U, y_5^U > \tag{7}$$

where y_i^U is the distance of top view point, which has coordinate $x = x_i$, from the upper side of the surrounding rectangle.

Similarly, for the down view:

$$< y_1^D, y_2^D, y_3^D, y_4^D, y_5^D > \tag{8}$$

where y_i^D is the distance of down view point, which has coordinate $x = x_i$, from the upper side of surrounding rectangle.

A method of choosing characteristic points and their quantity may vary. In our experiments we used five points equally spaced on the x axis. After calculating distance vectors as shown above, we can move to build the rational function $H(s)$.

Experiments were carried out for different ways of creating rational function, they are:

(1) Polynomial $Q(s)$ is formed using distance vector evaluated for the top and down views, $P(s)$ is formed from a vector containing x values:

$$H_U(s) = \frac{x_0 + x_1 s + x_2 s^2 + \ldots + x_n s^n}{y_0^U + y_1^U s + y_2^U s^2 + \ldots + y_n^U s^n} \tag{9}$$

$$H_D(s) = \frac{x_0 + x_1 s + x_2 s^2 + \ldots + x_n s^n}{y_0^D + y_1^D s + y_2^D s^2 + \ldots + y_n^D s^n} \tag{10}$$

(2) Polynomial $P(s)$ is formed using distance vector evaluated for the top and down views, $Q(s)$ is formed from a vector containing x values:

$$H_U(s) = \frac{y_0^U + y_1^U s + y_2^U s^2 + \ldots + y_n^U s^n}{x_0 + x_1 s + x_2 s^2 + \ldots + x_n s^n} \tag{11}$$

$$H_D(s) = \frac{y_0^D + y_1^D s + y_2^D s^2 + \ldots + y_n^D s^n}{x_0 + x_1 s + x_2 s^2 + \ldots + x_n s^n} \tag{12}$$

(3) Polynomial *P(s)* is formed using distance vector evaluated for the down view, *Q(s)* is formed using distance vector evaluated for the top view:

$$H(s) = \frac{y_0^D + y_1^D s + y_2^D s^2 + \ldots + y_n^D s^n}{y_0^U + y_1^U s + y_2^U s^2 + \ldots + y_n^U s^n} \tag{13}$$

as a result we get one function describing entire letter.

(4) Polynomial *Q(s)* is formed using distance vector evaluated for the down view, *P(s)* is formed using distance vector evaluated for the top view:

$$H(s) = \frac{y_0^U + y_1^U s + y_2^U s^2 + \ldots + y_n^U s^n}{y_0^D + y_1^D s + y_2^D s^2 + \ldots + y_n^D s^n} \tag{14}$$

Then, according to the theory in [1], the feature vector is calculated and used in classification process.

4. RESULTS

Experiments were carried out for letters *A*, *V*, *N* and *O* written using twelve different font styles. We projected five characteristic points from both views. For each letter the 30-degree Taylor series was calculated, which gave us 30-element feature vector. The following graphs present eigenvalues for all letters taking 6 of each. The first one shows results achieved by applying rational function (9).

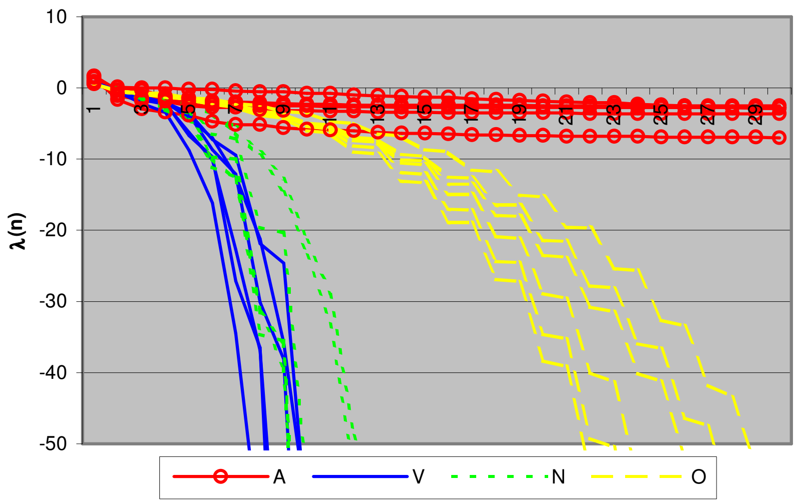


Fig. 3. The graph of minimal eigenvalues for rational function in Equation 9

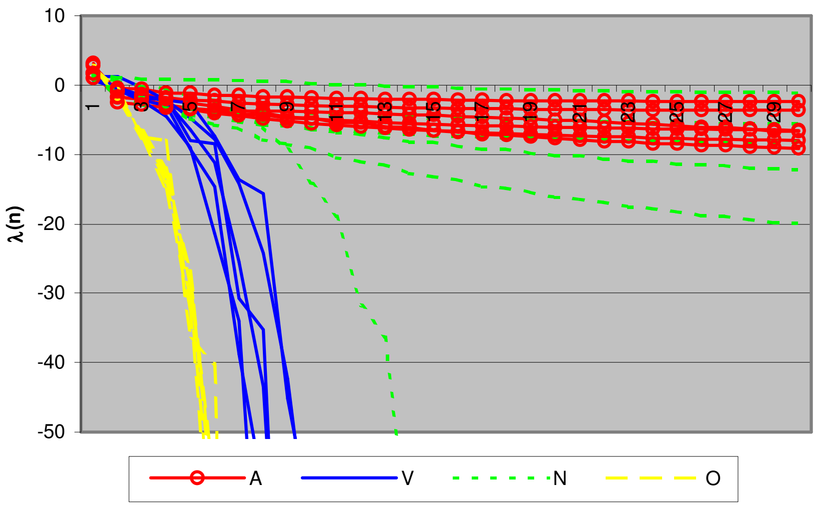


Fig. 4. The graph of minimal eigenvalues for rational function in Eq. 10

As can be seen from the above graphs, the feature vectors (minimal eigenvalues vectors) can be easily distinguished. The fact, that characteristics of *N* and *V* for the top view, *V* and *O* or *A* and *N* for the down view overlap isn't crucial, because for classification purpose, vectors from both views are used, which allow us to recognize them. Besides, this effect is easy to understand. For example, characteristics of top views of letters *N* and *V* are almost the same, so the results should be similar.

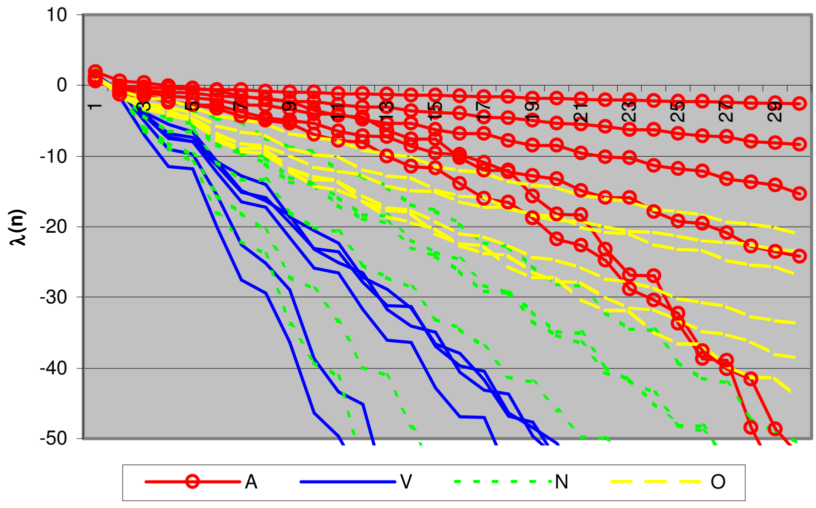


Fig. 5. The graph of minimal eigenvalues for rational function in Eq. 11

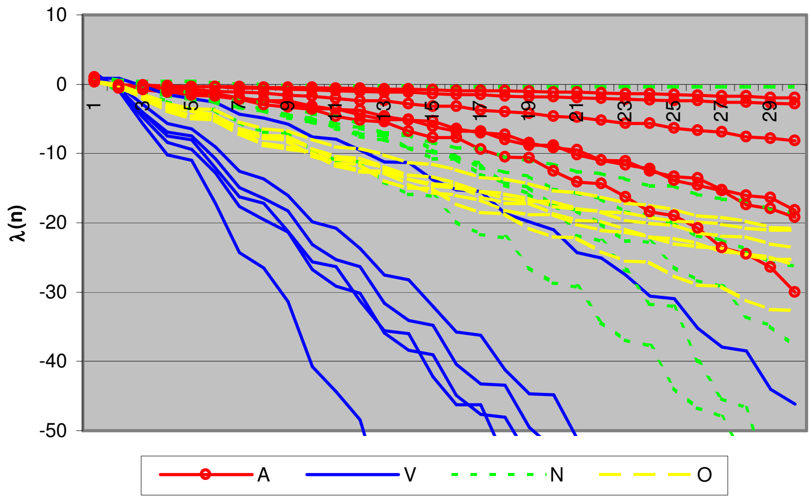


Fig. 6. The graph of minimal eigenvalues for rational function in Eq. 12

The results presented in Fig. 5 and Fig. 6 aren't as good as the previous ones in Fig. 3 and 4. The effect of overlapping is greater and the characteristics for single character aren't concentrated. However, they are grouping in clusters so they can also be separated.

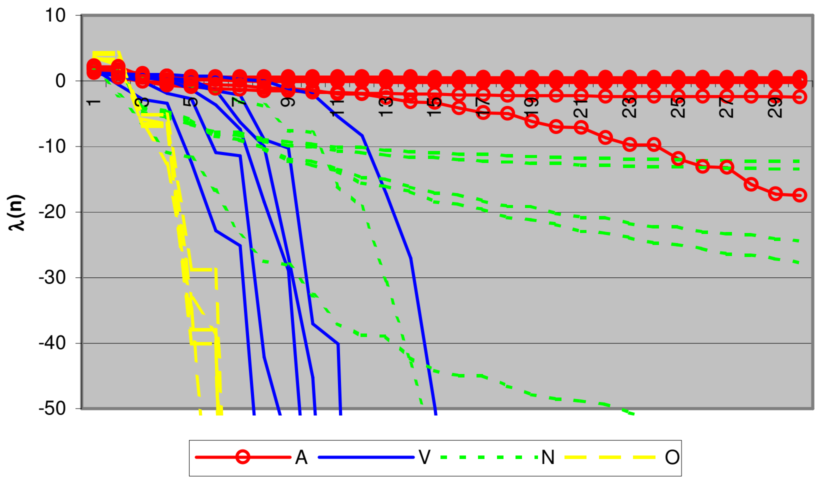


Fig. 7. The graph of minimal eigenvalues for rational function in Eq. 13

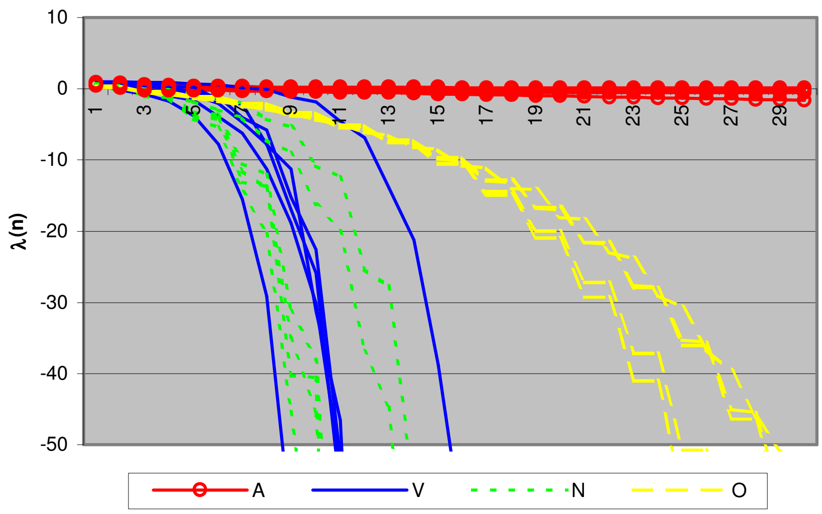


Fig. 8. The graph of minimal eigenvalues for the rational function in Eq. 14

5. CONCLUSIONS AND FUTURE PLANS

The results are good and encouraging to further work. We are doing more research on other types of letters. Some of the letters cannot be recognized by tracing only top and down views (for example, *E* and *Z*) – that is why we are going to analyze also the left and right views. The next step is to test our method using distorted characters and handwritten script.

6. ACKNOWLEDGEMENT

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