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**INTERNATIONAL SCIENTIFIC  
AND PRACTICAL CONFERENCE  
"TRENDS IN SCIENCE AND PRACTICE OF TODAY"**

**Ankara, Turkey  
October 19-22, 2021**

**ISBN 978-1-63972-065-1**

**DOI 10.46299/ISG.2021.II.V**

# **TRENDS IN SCIENCE AND PRACTICE OF TODAY**

Abstracts of V International Scientific and Practical Conference

Ankara, Turkey  
October 19 – 22, 2021

Library of Congress Cataloging-in-Publication Data

UDC 01.1

The V International Science Conference «Trends in science and practice of today»,  
October 19 – 22, 2021, Ankara, Turkey. 478 p.

ISBN - 978-1-63972-065-1

DOI - 10.46299/ISG.2021.II.V

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# FEATURES OF METHODS OF ISSUATION OF KEY AREAS AND VECTOR RECOGNITION OF MANUSCRIPT SYMBOLS ON THE IMAGE

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When recognizing handwritten symbols in images, it is important to identify an area that contains handwritten characters. To identify such areas often use the method of histograms [1, 2]. The images are scanned sequentially, summing up the number of pixels in the line, based on the obtained results build a histogram. Then the analysis of the histogram for highs and lows is performed [3-5]. The maximum value indicates the location of the key area that contains the characters. It should be noted that this approach is effective when the rows are arranged horizontally.

If the rows are not horizontal, you need to repeatedly scan in different directions and choose the direction that provides the most pronounced highs and lows on the resulting histogram. This fact imposes significant computational limitations and requires large resources of machine time and memory [6].

It is necessary to propose a modified method based on the detection of text areas by morphological processing with subsequent detection of related areas, in addition, this method will determine the orientation of the input image, which greatly simplifies the recognition procedure and increases the efficiency of the recognition system [7-10].

In the general case, the model for defining text areas in the image can be expressed by the following formula:

$$TZ = \langle \{On_{TZ}\}, \{Om_{TZ}\}, \{Oc_{TZ}\}, \{Os_{TZ}\} \rangle,$$

where  $\{On_{TZ}\}$  – operator of preliminary normalization of text zones;

$\{Om_{TZ}\}$  – morphological processing operator;

$\{Oc_{TZ}\}$  – character categorization operator;

$\{Os_{TZ}\}$  – operator finding special characters.

The modified detection method can be divided into the following steps [11]:

- Pre-processing stage (noise reduction, binarization);
- Morphological processing (expansion and compression operations);
- Identifying related areas and constructing text areas;
- Determining the angle of rotation of text areas relative to the horizontal direction.

At the pre-processing stage, various filtering methods are used to remove image noise. The simplest are smoothing filters: linear and median. Since the image with

handwritten symbols is often a two-color image, it is advisable to convert it into binary by the method of threshold binarization [12]. You can use the average brightness of the pixels of the image as a threshold. It should be noted that there are more complex schemes for selecting the threshold. However, since in this case only contour information is required, their use is impractical.

When threshold binarization, the assignment of the value of the source element is performed by the formula:

$$Q(i, j) = \begin{cases} 0, & \text{else } A(i, j) < P, \\ 1, & \text{else } A(i, j) \geq P, \end{cases}$$

where  $A(i, j)$  – the brightness value of the source image element;

$Q(i, j)$  – the value of the binary image;

$P$  – threshold value.

At the stage of morphological processing, the operation of expansion and compression is applied sequentially. The morphological algorithms involve digital images given by functions  $f(x, y)$  and  $b(x, y)$ , where is the function  $f(x, y)$  – original image is as well  $b(x, y)$  – primitive image.

Then the expansion operation  $f$  on  $b$  defined as:

$$(f \oplus b)(s, t) = \max\{f(s - x, t - y) + b(x, y)\} | (s - x, t - y) \in D_f(x, y) \in D_b),$$

where  $D_f$  and  $D_b$  – image definition areas  $f$  and  $b$  in accordance;

$s$  and  $t$  – coordinate shift along the axes  $X$  and  $Y$ .

The compression operation is defined in a similar way  $f$  on  $b$ :

$$(f \ominus b)(s, t) = \min\{f(s + x, t + y) - b(x, y)\} | (s + x, t + y) \in D_f(x, y) \in D_b),$$

where  $D_f$  and  $D_b$  – image definition areas  $f$  and  $b$  in accordance;

$s$  and  $t$  – coordinate shift along the axes  $X$  and  $Y$ .

Expansion operations use masks with an aperture of  $3 \times 5$ ,  $3 \times 7$ , and higher as primitives, as a result of which the contours of closely spaced characters will be linked to the general contour of the text area. Next, a compression operation is used to smooth the outer edges of the connected areas.

These operations can be performed sequentially several times for more efficient merging into common areas.

The study showed that for a mask with an aperture of  $3 \times 5$  it is necessary to perform an average of 3 operations of expansion and compression, and for a mask with an aperture of  $3 \times 7$  enough 1-2 operations of expansion and compression [12].

The associated areas are then marked with the surrounding markers. On the basis of the received markers the table of connectivity of the marked areas is constructed and binding of these areas in the general text zone with a mark of the given zone by an

index is carried out. The mean angles of text areas relative to the horizontal line are used to calculate the rotation angle of the entire image to provide better segmentation of text areas into individual characters.

The stage of transition to normalized images of individual symbols is associated with the selection of the outer contour of the symbol, the parameterization of the vector representation of the contour and the normalization of the vector representation [13-15]. If the task of selecting the outer contour of the object and parameterizing its vector representation is well done, then the normalization of the vector representation in the context of the task requires additional effort.

A feature of handwritten character recognition is the great variety of contours.

It is proposed to ensure the invariance to the scale and different styles of writing symbols by bringing the sum of the lengths of vectors to unity and choosing the directions of vectors in accordance with standard directions, and to consider the vector with the minimum length as the invariant of choosing the starting point.

If there are several vectors with a minimum length, special rules for selecting the starting point of the bypass are used, which are implemented at the learning stage of the system.

Thus, the model of normalization of the symbol image can be represented as:

$$VD = \langle \{Oo_{VD}\}, \{Ov_{VD}\}, \{On_{VD}\} \rangle,$$

where  $\{Oo_{VD}\}$  – the operator of the selection of the outer contour of the symbol;

$\{Ov_{VD}\}$  – operator parameterization vector representation of the contour;

$\{On_{VD}\}$  – vector representation normalization operator.

To build a vector model of the symbol and its classification, you must first find the reference points of the outer contour of the symbol.

The reference point is the point where the line describing the outer contour of the symbol image has a bend. To find such points, it is proposed to use a modified Roberts's filter. After applying this filter to the binary image, it is scanned for each point of the image belonging to the class of reference or non-reference points.

Modification of the filter allows you to get the output image in three gradations of pixel brightness. The reference point will have the maximum brightness value. After finding any of the reference points, the image is traversed along the outer contour with the sequential definition of all subsequent reference points.

A modified wave algorithm is used to bypass the image. The algorithm works with a two-dimensional array, which is an image matrix obtained after pre-processing and contains the inverse values of the brightness of the pixels of the image. In the process of the algorithm is propagated in 4 directions from the previous state.

Modification of the algorithm is a directed propagation of the direction along the intended contour. This algorithm searches for the connectivity of reference points from the first reference point found (when scanning an image from left to right and from top to bottom) to the last reference point in a given contour.

After finding the reference points and entering them in the table, a vector model is built. The beginning of each subsequent vector  $V_{i+1}$  is at the end of the previous one  $V_i$ , forming a closed loop.

Each vector is characterized by a pair of coordinates: the angle relative to the horizontal line (*alfa*) and the length of the vector (*len*). Determination of vector coordinates  $V_i = (Len_i, Alfa_i)$  carried out by moving from absolute coordinates to relative coordinates.

After construction, the vector model is subjected to the procedures of compaction and normalization.

Sealing refers to the removal of insignificant vectors that connect adjacent points. After compaction, the normalization procedure is performed, which consists in normalizing the lengths of vectors and angles of vectors in the directions.

The normalization of the length is as follows: the sum of the lengths of the vectors in the model is carried out to a unit length, and all other lengths of the vectors are scaled accordingly.

Normalization of angles in the directions is as follows: calculate the closest direction of the vector to the current vector in the model, the normalization of the angle to this direction.

Thus, in accordance with the proposed construction of the vector model, depending on the choice of the initial reference point, you can get variants of the vector model. Sequential search of all received models requires additional resources of time and memory in the process of recognition.

The algorithm for finding the «best» vector of the model is as follows:

Step 1. The first found vector of minimum length is selected.

Step 2. Determine the total path length to further vectors of minimum length.

Step 3. The next vector of minimum length is selected.

Step 4. If not all minimum vectors are processed, then go to Step 2.

Step 5. Select the vector from which the total path length is minimal. This vector is considered the “best”.

Different implementations of handwritten signs of the same class differ from each other in transfer, scale, inclination, proportions, etc.

To ensure the invariance of the description to these transformations, sequences of elementary directions are considered, each of which characterizes the relative position of two adjacent points of the image.

The method of maximum likelihood is used to build the recognition algorithm. The decisive rule is determined by the expression:

$$V_j^0 = \arg \max_j \max_l P(X_l/E_l^j).$$

The maximum is sought for all classes and for all possible length standards  $l$ . This rule looks for a standard length  $l$ , closest to the image  $X_l$ .

To implement the decision rule instead of the value  $P(X_l/E_l^j)$  you can use a monotonically decreasing function from this value, for example:

$$g(X_l/E_l^j) = \sum_{i=1}^n g(x_i, e_i^j),$$

where  $g(X_l/E_l^j)$  – the proximity function of the elements of the input image  $x_i$ , and standard  $e_i^j$ , which is determined by a positive integer proportional to the absolute value of the angle between the two compared elementary directions, as well as the difference in the lengths of the elements in the vector model of the standard and this input image.

Thus, the decisive rule can be expressed as follows:

$$V_j^0 = \arg \max_j \max_l \sum_{i=1}^{n=l} g(x_i, e_i^j).$$

Thus, in image recognition tasks, the key point is to highlight some of the characteristic features of the image. In particular, when recognizing handwritten symbols, such a characteristic feature may be the image of the outer contour. The use of a vector approach to describe the outer contour of the image of handwritten symbols is the most effective because it allows to obtain invariance with respect to the transformations of the affinity group.

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