The Second International Conference "Problems of Cybernetics and Informatics"
September 10-12, 2008, Baku, Azerbaijan. Section #2 "Intellectual Systems"
www.pci2008.science.az/2/16.pdf

FUZZY APPROACH TO THE STRUCTURED METHOD OF RECOGNITION OF PRINTED AND HANDWRITTEN SYMBOLS

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Lately, with the progress of computer technology on a large scale, there has been an increase of interest to recognition systems. As a result, application fields of computers are expanding in all directions. At the present time a lot of work is being done in the fields of voice, printed handwriting, fingerprints recognition, medical diagnostics, weather forecasting, stocks exchange forecasting and speed determination. All of the above mentioned problems have similar solution method. Their solutions are realized with artificial neuronal networks, fuzzy sets theory, structured recognition method[1]. There is a multitude of methods and models to solve these problems. Each of these methods and models has their strong, as well as weak points. There are two types of recognition systems – online and offline. At the present time, there is much corporative software for printed handwriting recognition, and some of this software can be used in recognition of printed handwriting text in Azerbaijani. Main goal of this work is to increase the quality of these programs.

For solution of this problem structured method of recognition of printed handwriting is reviewed. More precisely, the letter structure of the problem is divided according to its straight line, curve and very curve features. Then amount of these features per letter is determined[2].

While constructing a recognition system, one faces a lot of problems. Main problems are extraction of features. Even though there are a multitude of mathematical models for features' extraction, none of these models can reach the human preciseness. This is one of the biggest problems. When it comes to recognition of speed, some problems are unsatisfactory scanning of the picture, deleted parts on the picture or unnecessary objects on the picture.

The most important condition for the construction of recognition system is determination of features (characteristics that enable distinction between objects) and their analysis.

It is required to solve some problems before constructing recognition system.

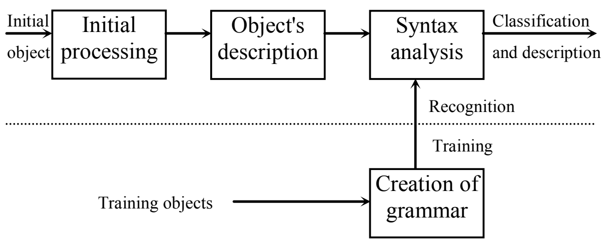
- Find a lot of features to distinguish objects
- Choose features that hold more information
- Construct a procedure needed to objects' classification

To increase the quality of recognition, additional dictionaries, databases are linked to the system. Usage of databases gives the following abilities to recognition system.

- Addition of new data to database after recognition
- Possibility of new learning after analysis of database
- Possibility of using the database during recognition

After getting the abilities shown above, system executes these operations itself. This method was already used in printed handwriting recognition system and as a result, the quality of system was increased.

System of recognition of text using syntax method could be viewed as a device consisting of 3 blocks – initial processing block, object visualization block and syntax analysis block.



1.1. Diagram the structured method of recognition

Initial processing block performs the functions of object's coding, approximation, filtration, restoration and improvement. Initial object is encoded and approximated to make further processing easier. For example, black-and-white picture could be shown as a matrix consisting of ones and zeroes, and curve as a reports taken at separate time points or a collection of multipliers resulting after Fourier transformation of this curve. To make processing in other blocks of system more effective, some kind of "data compression" is usually used in this block. Then filtration, restoration, improvement for removal of noise, correction of corruptions and methods to improve the characteristics of coded or approximated objects are applied. After the initial processing, every object is shown in verbal structure. Procedure of object's description consists of segmentation and choice of features. In this phase every object is shown with feature set and particular operations. The problem of correctness of object's description (that is, whether it is contained in the class that is described with given syntax) is dealt with syntax analysis. If syntax description of the object is correct, then this block is expressed with grammatical units or grammatical differentiation tree, depending on syntax analysis or grammatical differentiation. Otherwise the object is either removed, or analyzed using other given grammar. The simplest form of recognition is comparing with etalon. Chain of features that describe initial object is compared to chain of features that form etalon. The closest one from these images according to some given condition is chosen.

Encoding and approximation. To process data on computers, first it is transformed to digital form (given by time and position functions in space) and then compressed using encoding or approximation schemes. Let us take one dimensional function (for example, curve) as an object. From theorems below, we get that given function can be exactly restored using its values at finite calculation points.

Theorem: Assume that Fourier transformation of $f(t)$ is equals to zero outside of $W \le \omega \le W$ interval. Then this function can be fully restored using the values whose distance from each other is not more than $(1/2)\ W$.

Most of the times, values of function outside of $W \le \omega \le W$ interval are near zero. That is why just an approximation is obtained as a result of function's restoration with help of calculations.

Filtration, restoration and improvement. Assume that F is a set of functions that describe every object and T is a transformation operation upon time and space, which is defined in set F. If for each $f \in F$, condition $\varphi(T(f))=T(\varphi(f))$ is true, then operation φ is called invariant. A characteristic of these features is that their impact on function's value in each point in time and space does not depend on this time and location of point. For two-dimensional continuous case, the result of $\varphi(f)$ operation can be shown as

$$\varphi(f(x,y)) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} g_\varphi(x-u, y-v) f(u,v)\,du\,dv = f * g_\varphi$$

Function g_φ is called distribution function of operation φ. It can be interpreted as an application of operation φ on one-point function f that is different from zero only at one point.

Segmentation. There doesn't exist a universal method for segmentation - division image into fragments. Different methods of segmentation could be useful depending on nature of analyzed image. For example, when recognizing pictures consisting of lines or symbols, the distinction of these symbols in black from white background can be done with the help of simple edge detection operation. Another approach to fragments' choice is the method of "edge (or contour) watching". Application of this method allows not only choice of fragments, but also obtaining information about the form of image. Assume that, S_p is singly connected element of object and $\overline{S_p}$ is this element's addition. Assume that, B is set of border points of fragment S_p and $x_0=(i_0, j_0)$ is the first point of B. Because (i_0, j_0) is border point of S_p, at least one of the points (i_0+1, j_0), (i_0-1, j_0), (i_0, j_0+1), (i_0, j_0-1) must be a part of $\overline{S_p}$ set. Denote this point as y_0^1. Starting from y_0^1 count eight points that are neighbors of (i_0, j_0) counterclockwise, so that fragment S_p stays at the left side. We obtain $y_0^1, y_0^2,..., y_0^8$ sequence as a result. If neither of points y_0^3, y_0^5, y_0^7 are contained in set S_p, point x_0 is this set's only element. Assume that it is not the case, and y_0^{2k+1} is the first point of sequence contained in S_p. Then next element of set B - x_1 is determined using following method:

$$x_1 = \begin{cases} y_0^{2k+1}, y_0^{2k} \in \overline{S_p}, \\ y_0^{2k}, y_0^{2k} \in S_p. \end{cases}$$

To find the next border point, the neighbor point of x_1, which is contained in $\overline{S_p}$ (y_0^{2k} or y_0^{2k+1}) is chosen, denoted as y_1^1 and the above shown procedure is repeated.

Extraction of features in recognition system. Every characteristic of image is used. Segmentation of images is dependent on particular objects, colors of image's pixels etc. It is very hard to determine these features. Low quality of picture and noise are problems in determination of features. In this case extraction of features must be characterized by geometrical connections and functions. Usage of geometrical methods in recognition is very widespread. This also depends on object in the image and its qualities.

The following can be used as features:

– Area of the image, amount of pixels in the image, time for image's segmentation

– Amount of pixels in rows and columns of the picture.

– Length of images contour in pixels

– Parameter of image's form $K = \frac{L^2}{S}$, here L is length of contour, S is area.

– Coordinates of contour's extremum points, e.g. the top point of polygon, if contours consist of line segments.

– Finding maximum and minimum of vector's radius. (connecting of contour center with its brightness center)

– Coordinates of characteristic points of image (brightness center, contour center or the center of portrayed rectangle)

– Distance between portrayed rectangle and brightness center

– Topological characteristics of the image, e.g. amount of its contour's extreme points.

Some features shown above are very easily determined. These are, for example, area of image, length of contour etc. Extraction of other features e.g. coordinates of contour's extreme points or orientation parameter needs construction of very complicated procedures[3].

Brightness center of an image is given by the following coordinates in the picture:

$$x_c = \frac{\sum_{x,y=1}^{M,N} xf(x,y)}{\sum_{x,y=1}^{M,N} f(x,y)}, \quad y_c = \frac{\sum_{x,y=1}^{M,N} yf(x,y)}{\sum_{x,y=1}^{M,N} f(x,y)},$$

Here x,y are coordinates of the pixel. M,N are dimensions of the picture, $f(x,y)$ is the brightness of the image at coordinates x,y. For binary images $f(x,y)=1$ is true, so numerator in formula is the sum of the pixels in rows and columns of the image, and denominator is the area of the image. Contour center is calculated analogically.

The main problems encountered during features extraction for recognition process are the following:

– The importance of different independent features, but existence of only one feature. For example, area is often missed.

– Difficulty of extracting different features, all of these features should be determined using identical simple method.

A symbol on the scanned paper is divided into rectangular parts.

Coordinates of points in each part are determined, then the table consisting of columns (*x,y,s*) is constructed, with *s* being length of broken lines that approximate the curve. Using the smallest squares method

$$x=x(s)=a_1s^2+b_1s+c_1,ç \qquad y=y(s)=a_2s^2+b_2s+c_2$$

dependencies are constructed, for each *s* parameter

$$k(s)=\frac{|x'y''-y'x''|}{\left(x'^2+y'^2\right)^{3/2}}$$

is calculated and their arithmetic mean *k* is found. So, in every part one or several *k* values are obtained. "D", "E", "LE" terms for "curved" fuzzy set are constructed. To determine nature of trajectory in analyzed part, gaussoid relationship function that depends on *k* is constructed.

$$\mu_D(k)=e^{-\frac{(k-b_1)}{2c_1^2}},\ \mu_E(k)=e^{-\frac{(k-b_2)}{2c_2^2}},\ \mu_{LE}(k)=e^{-\frac{(k-b_3)}{2c_3^2}}$$

Operations b_i, c_i, i=1,3 are defined by expert.

Depending on the values of these functions, defuzzyfication block determines, whether the trajectory in this part is a straight line or a curve. As a result amount of straight lines and curves in symbol is calculated.

It also can happen that points in rectangle's parts form neither straight line nor a curve. To determine this, a number ε is chosen and if for this number condition

$$\sum_{i=1}^{n}\left(x_i-\frac{\sum_{j=1}^{n}x_j}{n}\right)^2+\sum_{i=1}^{n}\left(y_i-\frac{\sum_{j=1}^{n}y_j}{n}\right)^2\le\varepsilon$$

is true, then set of points $(x_i,y_i), i=1,2,...,n$ form neither straight line nor a curve.

Features are extracted for the elements of training set in recognition process. That is, for every class, set of features is written and then neuronal network is trained. Current symbols' codes are created and it is determined using neuronal network, to which class they pass the best.

Literature

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