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About One Principle to Identification of Shape of Object

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Process of recognition of the shape of graphic objects consists of several stages. At the first stage as a result of processing images allocate some set of characteristic properties of some object, and on the second, make identification of object by means of comparison of these properties with properties of the sample. Presence of noise on real images often leads to disturbance of quantity and values in a set of such characteristic properties. In job methods of preliminary processing of images for receiving of set characteristic properties of objects and present methods of the identification are stated, allowing identifying the shape of graphic objects in conditions when the part of a set of characteristic properties of object concerning the sample is absent or is deformed by noise. Feature of the offered methods is their invariance to affine to transformations of the shape of object, and also high speed of identification, not dependent on complexity of identified object.

Key words and phrases: Image Processing, Pattern Recognition, Computer Geometry.

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1. Introduction

The decision of task of identification of shape of graphic objects essentially differs from other problems of recognition by that first, images entering on an input of the recognized device can include noise and have geometrical distortions. And secondly, process of recognition of the shape of object as a rule is based on some characteristic hardly formalized properties with which is necessary to receive from the image. And if the first part – processing of the image now is well studied, the second part – process of recognition is represented very complex task which decision can be subdivided into two stages. At the first stage it is necessary to define native characteristic properties of recognized object, and – on the second to develop a method allowing to these properties to make comparison of some sample and recognized object. Complexity of the second stage of process of identification consists of in necessity to operate hardly formalized and verbally not expressed characteristics of the shape of graphic objects [1, 2].

Recently the big attention is given one of directions of recognition at which as a result of primary image processing the contour of some object is allocated [3–6]. This contour further is transformed in the set of the points representing some closed curve [7–9]. As the description of such contour values of function of curvature are used [10–17], and as characteristic properties the points having it the maximal values are used [18–21], see also [22, 23]. Despite of great number of variants of the decision of such problem, stability of its decision is absent, as at the real image always presenting noise which lead to distortion of contour of curve and, hence to change of its curvature. And it in turn results or in smoothing some extremum (that is to removal), or to occurrence of new points with the high curvature, not being characteristic properties of object.

Thus, if to reject the first part of a problem of recognition – image processing and to investigate the second part then a problem of identification to be used in the formulation of development of the methods, allowing to identify the form of objects at partially deformed contour. Analyzing above listed sources, it is obviously, that these methods are reduced in general to robust to receiving of function of curvature by some tabular defined of curve and do not mention methods of identification of the shape of object. The purpose of the present job is the statement of the modified methods of formalization of characteristic properties of shape of objects and representation of methods of their identification.

2. Image Processing Stage

Now for image processing there are well studied methods of primary processing and receiving of the closed contours in the form of the verbal description [2, 3], not only in details stated in the literature, but also realized in widely applied packages, such as Matlab and LabVIEW. Using these packages for preliminary processing of the image and receiving of contours, it is possible to concentrate attention to methods of construction of the formal description of shape of object and development of methods of identification on their basis.

On fig. 1 the result of processing of a silhouette of the plane (at the left above) with small noise level is shown. For reception of a contour of object (at the left above) the following sequence of Matlab functions from package Image Processing has been used: loading of the image; for removal of noise using a filtration; and method Contour Following [24] for receiving of a contour of object.

For identification of the shape of object as initial data the contour of the object has been used received as a result of preliminary processing the image. It consisting from set of points ($n >> 1$) — $P_1P_2P_3...P_n$, closed parameterized flat curve $\Gamma(t) = (x(t), y(t))$, $1 \leq t \leq n$. For construction of characteristic properties of object method Arch Height for the first time published in 1992 [25], and in further repeatedly modified, for example in [26] is used. The initial idea of this method consist in calculation Euclid of distance d_i, between a point of a curve – P_i and a chord as shown in fig. 2 which is proportional to value of the module of curvature in this point.

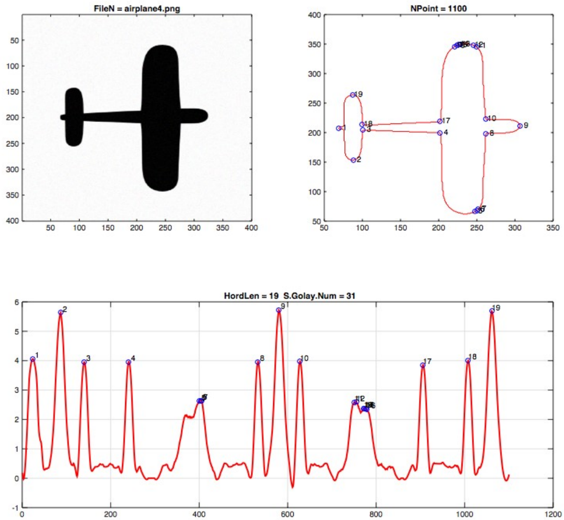

Figure 1. Silhouette of the plane with added white noise (at the left above), its received contour (on the right above) with the put points of high curvature and function of curvature of a contour (from below), with points of the maximal curvature.

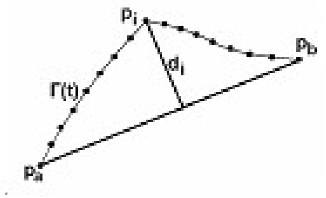

Figure 2. A fragment of a curve Γ with points P_k and a chord (P_i, P_j).

As a result of moving of the chord along the contour the function of curvature represented on fig. 1 (below) turns out. As characteristic properties of such curve we shall use a array of values of the greatest an extremum, which are received with use of function ***findpeaks()*** from set Signal Processing Toolbox of package Matlab. For cutting off of small extremum was using value of some threshold calculated on the basis of a mathematical expectation and a variance of function of curvature. As a result of this operation we shall receive a array of points of coordinates in which contour has the maximal curvature, as shown numbered points on fig. 1.

3. Process of Identification

For realization of process of identification of object in accounting of invariance to group of affine transformations it is necessary to consider some factors. Namely, at presence of noise, change of scale of a contour, and also its turn it is available a variation of values of extreme points as aside increases, and reduction. In the first case it means occurrence of new points in a array, and in the second their cutting off. Thus, for identification of the shape of real object, is complicated because of variations of quantity of points of extreme in arrays of the sample and current object.

The method has been developed for the decision of the problem identification shape of object independently of its position on the image (shift), quantities of points of its contour (scale) and a angle of its turn. The method is similar to metrics of geometrical correlation [27] and consists in performance of following operations.

First, we shall transform coordinates received on antecedent a step of a array of extreme points from Cartesian in polar, using as the center of coordinates of polar system the centre of gravity of object. However in difference from methods of geometrical correlation [27–29], the present method is based only on use of a array of points of extreme. Besides as preliminary operation of identification we normalize arrays of object and the sample concerning their maximal value. Due to these operations, we receive invariance to shift and scale object and the sample.

Secondly for a statement of a method of identification, we formalize record of set of points abscises the sample on which we shall make identification in next form.

Definition 1. We shall write down set of points of extreme of function of the sample $f(t)$ as $G_f = \{a = t_0 < t_1 < ... < t_l = b\}$ where t_i – angles of turn of values of $f(t)$ in polar coordinates, and set of points of identified object as $G_h = \{c = \tau_0 < \tau_1 < ... < \tau_m = d\}$ for function of object $h(\tau)$. Let as the quantity of points of the sample will be more than object, that is $l > m$, otherwise we interchange the position object with the standard.

For construction of the metrics of identification we shall add m points to set of the sample in the following way:

$$G_f^* = \{t_0, t_1, ..., t_l, (t_{l+1} = t_l + t_1 - t_0), ..., (t_{l+m} = t_l + t_m - t_0)\}.$$

That is we shall add in the end of a array its initial fragment from m points.

Definition 2. For some set of points $G_f = \{a = t_0 < t_1 < ... < t_l = b\}$ we shall define its mirror set as $G^m = \{b = y_0 = t_n > y_1 = t_{n-1} > ... > y_n = t_0 = a\}$.

Definition 3. We shall write down two-dimensional function of a difference between $f(t)$ and $h(t)$ as $\eta_{i,j} = f(t_{i+j}) - h(\tau_i)$, $j = \overline{0, (l-m)}$, $i = \overline{0, m}$, $\tau \in G_h$, $t \in G_f$.

Definition 4. We shall write down discrete function of an absolute error:

$$\delta_j = \frac{1}{m+1} \sum_{i=0}^{m} |\eta_{i,j}|, \quad j = \overline{0, (l-m)}.$$

And discrete function relative error:

$$\sigma_j = \frac{1}{m+1} \sum_{i=0}^{m} |\delta_j - \eta_{i,j}|, \quad j = \overline{0, (l-m)}.$$

Definition 5. We shall write down function of recognition for identification of curves at incomplete data on the basis of correlation on incomplete data #1 (CID1) as

$$\lambda_{nk1} = \begin{cases} 1, & (\rho_{nk1} < \varepsilon_{nk1}) \vee (\rho_{nk1}^m < \varepsilon_{nk1}), \\ 0, & (\rho_{nk1} \geq \varepsilon_{nk1}) \wedge (\rho_{nk1}^m \geq \varepsilon_{nk1}). \end{cases} \tag{1}$$

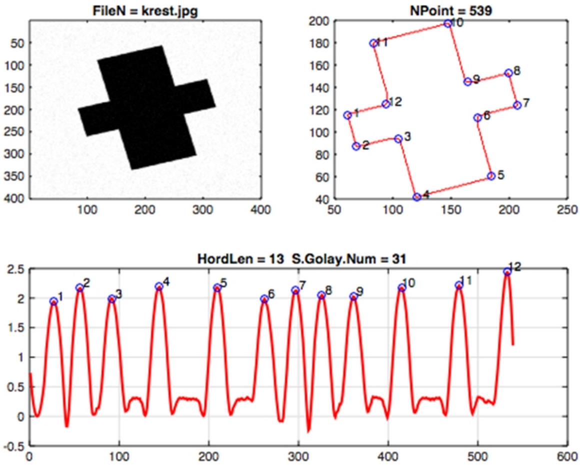

Figure 3. Object "Cross" with adding noise. Its contour and functions of curvature of a contour with points of maxima curvature

Where $\rho_{nk1} = \min_j \delta_j$ the metrics of correlation on incomplete data #1 and ρ^m_{nk1} the metrics of correlation on incomplete data #1, calculated on a mirror data set and ε_{nk1} – the classification's tolerance. Equality $\lambda_{nk1} = 1$ means successful classification object in relation to the sample, thus value j corresponds to a corner of turn of object concerning the sample.

Definition 6. We shall write down function of recognition for identification of curves at incomplete data on the basis of correlation on incomplete data #2 (CID2) as

$$\lambda_{nk2} = \begin{cases} 1, & (\rho_{nk2} < \varepsilon_{nk2}) \vee (\rho^m_{nk2} < \varepsilon_{nk2}), \\ 0, & (\rho_{nk2} \geq \varepsilon_{nk2}) \wedge (\rho^m_{nk2} \geq \varepsilon_{nk2}). \end{cases}$$

Where $\rho_{nk2} = \min_j \sigma_j$ the metrics of correlation on incomplete data #2 and ρ^m_{nk2} the metrics of correlation on incomplete data #2, calculated on a mirror data set and ε_{nk2} – the classification's tolerance. Equality $\lambda_{nk2} = 1$ means successful classification of object in relation to the sample, and value j corresponds to a corner of turn of object concerning the sample.

Let's consider examples of identification of simple objects on the basis of the introduced methods. So on fig. 3-4 the object of type "cross" and its deformed value is represented. The metrics calculated under the formula (1) for these objects is equal 0.0796, and for object "cross" silhouette of plane on fig. 1 – is equal 0.24, that is three times it is more. Statistical researches of values of metrics between objects various shapes (sample-nonsample) and one shape, but subjected affine to transformations; differ at the average three times. Establishing the classification's tolerance in the middle of an interval between mathematical expectations of metrics of type the sample-sample and the sample-nonsample, we shall receive the best results of recognition.

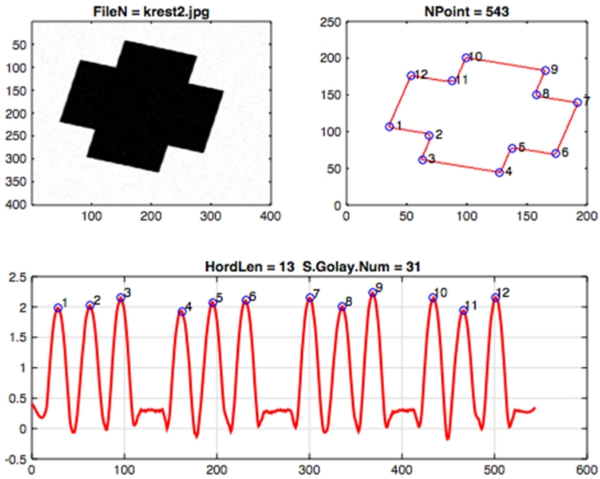

Figure 4. Object "Cross2" with adding noise. Its contour and functions of curvature of a contour with points of maxima curvature

4. Discussion

Development represented methods of identification on the basis of metrics of correlation on incomplete data pursues some the purposes.

First, to present a simple method of identification of the shape of the objects, possessing considerably smaller calculated effort, in comparison with the methods based on geometrical correlation [27–29]. Here it is necessary to note, that the offered methods practically non dependent from complexity of the shape of identified objects as suppose change of "precision of representation" of shape of object due to a choice of a level of cutting off of extremum of function of curvature and by that accuracy of representation of the shape of object.

Secondly, in the name of the considered metrics the property supposing absent or presence of additional extremum arising at function of curvature because of presence of noise on the input image is incorporated. So, for example, for a figure "krestDm2", shown on fig. 5-6 and having on two extreme it is less, value of the metrics between the given figure and object "cross" has increased approximately from 0.05 till, that makes less than 1%.

Calculation of the metrics between identical objects, but with is artificial the entered distortions, for example as on fig. 5-6. At the left in figure object with two smoothed corners and absent points of extreme, and on the right on the contrary with additional corners. Values of the calculated metrics equally 0.05, that allows to compare the shape of the deformed objects stable.

Thirdly, carried out researches show, that the given metrics work not only at presence affine transformations of identified objects, but also is much wider. So for example objects, represented on fig. 3-4 only it is informally possible to ranking identical shape of objects, so not exist groups of the transformations converting one these objects to another. Nevertheless their human eye will identify as the same object.

The presented methods can be applied in various areas of computer vision and a robotics, medicine, geology and cartography.

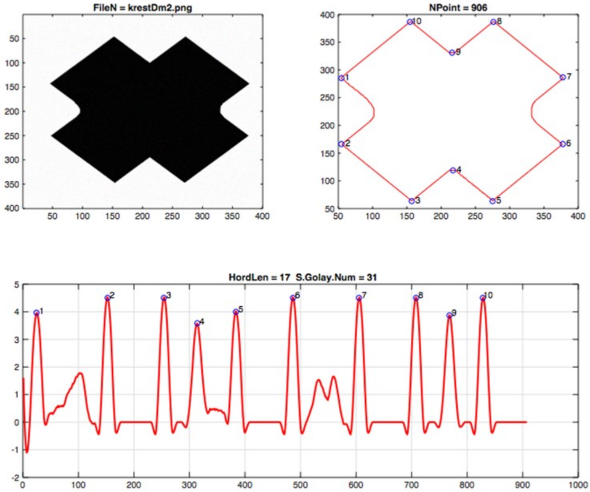

Figure 5. Object "KrestDp2", with additional corners. Below presented functions of curvature with points of maxima curvature.

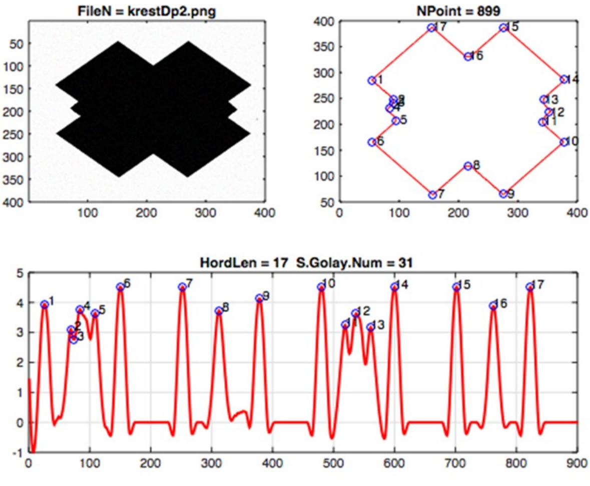

Figure 6. Object "KrestDm2" with two smoothed corners and object. Below presented functions of curvature with points of maxima curvature.

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