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Qualitative Representation and Evaluation of the Similarity of Forms of Lines of Contour Images

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Abstract: Automation of the analysis, comparison and search of graphic information on the contents allows to increase labor productivity of many experts. The quality of the recognition system is largely determined by what the signs of her images are considered. The purpose of research is development of a way of the substantial description and comparison of lines of outline drawings. It is offered to present a line form in the form of a linguistic variable. Experiments on comparison of contours of machine-building details and objects of satellite images which show high efficiency of the offered approach in respect of quality and speed are given.

Key words: Sign, shape of the lot, linguistic variable, contour mapping, assessment of similarity, drawing

INTRODUCTION

The problem of search and recognition of images arises in various spheres of activity. In machine-building design the means of search of drawings in a sketch (Barton and Love, 2005; Sousa and Fonseca, 2010) allowing designers in new projects more actively to apply the previous practices (the existing components, design decisions, technological processes) presented in a graphic form in archive of the enterprise are demanded. Systems of recognition of ancient manuscripts (Kornienko *et al*., 2011; Zelencov and Philippovich, 2011; Jerele *et al*., 2012) allow to increase efficiency of linguistic researches because becomes perhaps, automatically to analyze manuscripts various text tools. In a number of tasks of geoinformation monitoring (combination of pictures, a coordinate binding of objects), it is required to carry out search and automatic comparison of areal objects.

In relation to the listed problems methods of comparison and recognition in which some structural (graph) description of objects is under construction (Fu, 1974; Bunke and Sanfeliu, 1990; Arkhipov and Elantsev, 2014) are popular. The separate contour or skeleton of the image as a rule, breaks into separate sites of primitives (line), each of which is described by a set of attributes: relative length, curvature degree, type, form, etc. Process of comparison of objects consists in establishment, what making elements coincide/differ on the basis of consideration of attributes of elements. In our opinion, one of the most informative attributes of the line is "form". The person at the description of lines on images uses the qualitative concepts "straight line", "twisting", "the smoothly turning", etc. In the course of automatic comparison of images often there are situations when at the compared lines all simple attributes coincide and only the analysis of their form allows to make the right decision.

Comparison of structural descriptions of images (in particular, comparison of counts (Conte *et al*., 2004)) is difficult in the computing plan. During this process separate components are compared a large number of times, including repeatedly that is caused by existence of alternative solutions. Therefore, the speed with which similarity of components is estimated, plays very significant role.

The purpose of this research is development of the model of the "line shape" attribute providing high pithiness of the description and speed of comparison of lines of drawings, hand-written symbols and other planimetric objects.

Review of related works: In similar, researches of the line are described, generally low-level quantitative attributes such as the normalized length, symmetry degree, etc. It leads to decline in quality of recognition and search of images, limits possibilities of the analysis of graphic images.

In research (Hou and Ramani, 2008), structural approach to comparison of contours of machine-building

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details is offered. The contour is described at two levels: special points and groups of primitives between them. Groups of primitives are described by one parameter function of turn (Arkin *et al*., 1991) which displays change of tilt angles of tangents in the points which are consistently chosen on primitives of group. Comparison of groups of primitives happens as follows. On the compared chains couples of points evenly get out (points of each couple are equally removed from the beginnings of chains). Differences between values of functions of turn in the chosen points are calculated. Aggregation of these sizes on a certain formula is considered as degree of distinction of chains.

In research Zelencov and Philippovich (2011) proposed a method for recognition of cursive ancient Russian texts. As structural elements of letters lines and points of their crossing serve. Lines are described by the "way" and "form" attributes. A way of the line a chain code of angular measurements of the directions of round of the line for 10 steps. The form of the line can accept values "wide", "square", "high". The form is defined by a tilt angle of a diagonal of the describing line rectangle. Comparison of lines on these attributes happens in the indistinct way.

Approach Olsen *et al*. (2007) is directed on comparison of trajectories of movement of a feather in sign interfaces. The trajectory is represented as a point in k-dimensional priznakovy space by quantization of tilt angles of the pieces connecting the next points of a trajectory. Similarity of trajectories is defined by Evklidov's calculation distances between them in the specified feature space.

In a method of recognition of strokes of the Chinese symbols (Xu *et al*., 2012), the assessment of similarity of a stroke to reference lines on the basis of consideration of indistinct value of length and the direction of elements of strokes is carried out.

In research of, it is offered to distinguish hand-written symbols on the basis of B-splines. Process of recognition includes three stages:

- An image skeletonization
- Definition of control points of a B-spline which describes curve images
- Comparison of curves, using distinction between their control points which is calculated on a simple formula

It is specified that approach is not capable to distinguish a curve which is turned or stretched in some direction concerning a standard.

Our purpose is development of such substantial description of a form of lines which would be characterized by informational content, compactness would not lead to critical losses of information and would provide the high speed of comparison of lines.

MATERIALS AND METHODS

We suggest to present attribute of the "form" lines in the form of the Linguistic Variable (LV) (Zadeh, 1975). This formalism is attractive that allows to describe objects or the phenomena qualitative terms (substantially) and also indistinctly, i.e., in our case is steady against distortions.

Linguistic variable can be defined in a simplified form tuple <n, T, X> where; n, the name of the linguistic variable; T, set of phrases from natural or artificial language (terms) that can take the linguistic variables described by fuzzy sets on a universal set X. A fuzzy set is defined as follows:

$$A = \{(x, \mu_A(x))|x \in X\}$$

where, $\mu_A(x) \in [0,1]$ membership function which determines the grade of membership of x fuzzy set A. Let LV the form of the line accept the following values: straight line, left smooth turn, left cool turn, right smooth turn, right cool turn, twisting. Respectively, it is required to set six functions of accessory. For the purpose of acceleration of process we will analyze the line only once, calculating thus at once all degrees of accessory to possible values of LV.

Algorithm membership function given below, carries through the elements of line, analyzes their curvature and mutual deviations.

Algorithm membership function:
Input: The line a chain of pieces and arches (e_1, …, e_n).
Output: grade of membership $\{\mu^S, \mu^{LQ}, \mu^{RQ}, \mu^{LT}, \mu^{RT}, \mu^W\}$.
$\mu^S \leftarrow 1.0$
$\mu^{LQ}, \mu^{RQ}, \mu^{LT}, \mu^{RT}, \mu^{LW}, \mu^{RW} \leftarrow 0.0$
foreach e_i do
ConsiderCur
if i>1 then
NonsiderPrevAndCur
if ($\mu^{LW}>0$) and ($\mu^{RW}>0$) then

$$\mu^W - \frac{\min\left(\mu^{LW}, \mu^{RW}\right)}{\max\left(\mu^{LW}, \mu^{RW}\right)} \times \left(\mu^{LW} + \mu^{RW}\right)$$

else
$\mu^W \leftarrow 0.0$

In this algorithm $\mu^S \in [0, 1]$ belonging to the value "Direct", ..., $\mu^W \in [0, 1]$ belonging to the value of "meandering"; ConsiderCur procedure tailored to the particular current item; taken into account in the procedure ConsiderPrevAndCur deviation of the current element from the previous one.

Algorithm ConsiderCur:
$\mu^S \leftarrow \mu^S\text{-}f(\alpha_{Line} - \alpha_{e_i}^{Beg}, 0, 20)$
if e_i is an arch then
$\mu^S \leftarrow \mu^S\text{-}f(\alpha_{Line} - \alpha_{e_i}^{End}, 0, 20)$
$\Delta \leftarrow \alpha_{e_i}^{End} - \alpha_{e_i}^{Beg}$
$\mu^S \leftarrow \mu^S\text{-}f(\Delta, 0, 80)$
if e_i turns to the left then
$\mu^{LQ} \leftarrow \mu^{LQ}+f(\Delta, 9, 3)$
$\mu^{RQ} \leftarrow \mu^{RQ}\text{-}f(\Delta, 0, 3)$
$\mu^{RT} \leftarrow \mu^{RT}\text{-}f(1, 0, 1)$
$\mu^{LW} \leftarrow \mu^{LW}+f(\Delta, 9, 3)$
else
$\mu^{LQ} \leftarrow \mu^{LQ}\text{-}f(\Delta, 0, 3)$
$\mu^{RQ} \leftarrow \mu^{RQ}+f(\Delta, 9, 3)$
$\mu^{LT} \leftarrow \mu^{LT}\text{-}f(1, 0, 1)$
$\mu^{RW} \leftarrow \mu^{RW}+f(\Delta, 9, 3)$

Algorithm ConsiderPrevAndCur:
$\Delta \leftarrow \alpha_{e_{i-1}}^{End} - \alpha_{e_i}^{Beg}$
$\mu^S \leftarrow \mu^S\text{-}f(\Delta, 0, 10)$
$\mu^{LQ} \leftarrow \mu^{LQ}+g(\Delta, 5, 5)$
$\mu^{RQ} \leftarrow \mu^{RQ}+g(\Delta, -5, 5)$
$\mu^{LT} \leftarrow \mu^{LT}+g(\Delta, 15, 10)$
$\mu^{RT} \leftarrow \mu^{RT}+g(\Delta, -15, 10)$
if $\Delta>0$ then
$\mu^{LW} \leftarrow \mu^{LW}+f(\Delta, 0, 20)$
else
$\mu^{RW} \leftarrow \mu^{RW}+f(\Delta, 0, 20)$

Here, $\alpha_{e_i}^{Beg}$ and $\alpha_{e_i}^{End}$ tilt angles of tangents of the current element in a point of the beginning and end respectively; α_{Line} a tilt angle of the piece connecting the beginning and the end of the line; function $f(\omega, \beta, \gamma)$ has the following appearance:

$$\left(\frac{\omega-\beta}{\gamma}\right)\times\frac{\text{Length}(e_i)}{\sum_{K=1}^{n}\text{Length}(e_k)}$$

The $\alpha_{e_{i-1}}^{End}$ a tangent tilt angle in a point of the end of the previous element; function $g(\omega, \beta, \gamma)$ is calculated as follows:

$$1.0-\left(\frac{\omega-\beta}{\gamma}\right)^2\times\left(\frac{\min(\text{Length}(e_i),\text{Length}(e_{i-1}))}{\max(\text{Length}(e_i),\text{Length}(e_{i-1}))}\times\frac{}{(\text{Length}(e_i)+\text{Length}(e_{i-1}))}\right)$$

The values β and γ given to functions f and g were defined empirically during control of algorithm.

The method of estimating the difference in the form of lines: Evaluation of differences between the two lines on the attribute "form", presented in the form of a linguistic variable is based on the aggregation of differences between the degree of membership:

$$\text{Differences}_{\text{medsqua}}(l^1,l^2)=\sqrt{\frac{\sum(\mu_1(P_i)-\mu_2(P_i))^2}{n}}\times 100\%$$

Where:
l^1, l^2 = Lines being compared
$\{P_1,\ldots, P_n\}$ = Set of terms of a linguistic variable
$\mu_1(P_i)$ and $\mu_2(P_i)$ = Degrees of accessory of values of attribute to P_i term in l^1 and l^2, respectively

RESULTS

Experiments: The presented approach is realized in program system of graphic search of drawings of GrSearch (Kasimov *et al*., 2015).

In Fig. 1 examples of sites of external contours of machine-building details are given, their qualitative description and degree of mutual distinction is shown. In our approach, the description of the line is carried out concerning one of two of its ends. In this drawing, the qualitative description is given from the point of view of the left end.

In Fig. 2 the example of results of comparison of contours of details taking into account a form of sites is given. The coincided sites are displayed in the identical color.

Experiment on search of drawings of details in external contours in which the test set from 4000 drawings was used and 50 inquiries were executed showed that average completeness of results makes 74.9% and the average spent time 36 sec (Kasimov *et al*., 2015).

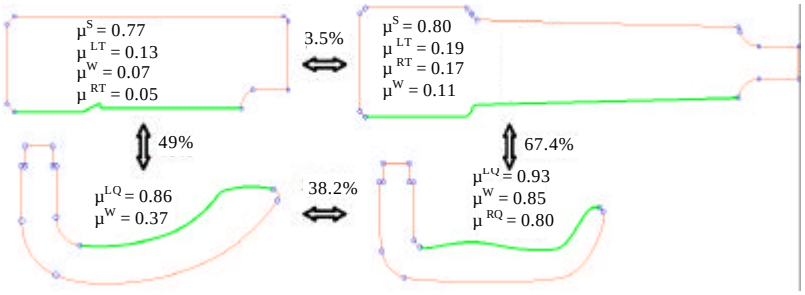

Fig. 1: Examples of processing of sites of machine-building details

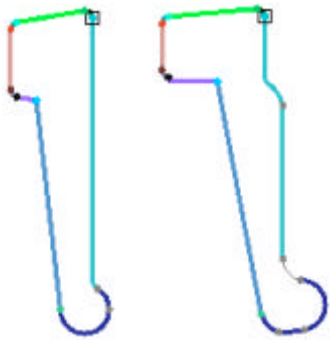

Fig. 2: Example of results of comparison of contours of details: Overall similarity assessment:88%; similarity of the matched fragments: 88%; size of the query's matched fragment: 100%; size of the analog's matched fraqment: 97%; count of the query's matched elements: 85%

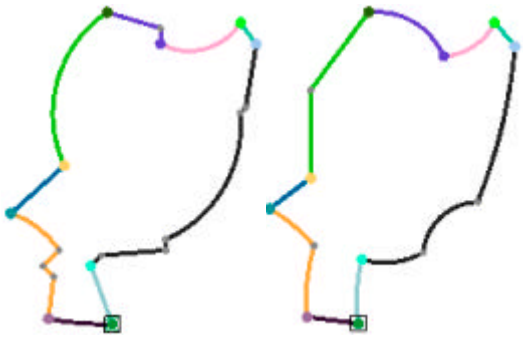

Fig. 3: Example of comparison the contours of water bodies: Overall similarity assessment: 66%; similarity of the matched fragments: 66%; size of the query's matched fragment: 100%; size of the analog's matched fraqment: 100%; count of the query's matched elements: 75%

There was also an experiment in search of water bodies on satellite imagery. The database contains satellite images of different localities in the Arkhangelsk region, Karelia and Buryatia; total 30 shots. The images were received in Yandex (https://maps.yandex.ru/) and Google Maps (https://maps.google.ru/). The total number of objects in the database reservoirs was 1,188 units. Inquiries were served by the objects of the same districts taken from the pictures created in other time. In Fig. 3, the example of results of the analysis of contours of reservoirs is presented.

Total statistics of this experiment the following. The 30 inquiries for 22 of them were set (73.3%) search was successful and the system in most cases removed in the list of results the necessary picture the first.

DISCUSSION

The offered algorithm of definition of a form of lines gives out quite adequate degrees of belonging to qualitative values of a form.

Speed of the algorithm due to its high linear complexity. Extracted sign forms invariant to rotation and scale. Due to use of the device of linguistic variables in the course of comparison of images there is an opportunity soundly and thus, quickly to analyze complex attributes (such as "form").

If we built the approach on the basis of training, for example by means of neural networks, it would be required to create a large number of the training examples and productivity, most likely would be lower as the same neural networks at a large number of neurons create big computing loading (Korolev and Kuchuganov, 2014).

It is obvious that we will apply our approach in various subject domains: comparison of contours of machine-building details; recognition of hand-written and old Slavic texts; comparison of contours of vulgar objects, etc.

CONCLUSION

In tasks of recognition and graphic search of images, there is a need of an assessment of similarity of separate elements of images in particular of chains of primitives (lines). It is possible to determine degree of similarity of two lines mainly by a form.

In research, the method of the description of a form of lines and also a method of an assessment of similarity of lines in a form is offered. Approach is based on use of the device of linguistic variables. Experiments showed high quality of the description and an assessment of similarity of forms of lines. Using this approachm, it is possible to conduct a meaningful analysis, comparison and image search.

The direction of further research is expansion of a set of possible values of a form, selection for new values of the corresponding functions of accessory, development and research of other ways of high-quality representation of signs of images.

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