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Development and Analysis of Segmentation Algorithm for Pattern Images

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ABSTRACT

This paper is devoted to modeling a method of the description of pattern images on the basis of power Laws characteristics. The algorithm of finding of power Laws characteristics on the basis of which the algorithm of segmentation of pattern images and an algorithm of a clustering by method to k – means is developed for segmentation specification and also their program realization has been constructed.

Researches of results of segmentation on the basis of a method of Laws characteristics are conducted. Results of researches allow to draw a conclusion on expediency of application of the developed algorithms for segmentation of pattern images and also for the solution of a problem of recognition and search in databases.

Keywords: Texture, image segmentation, clustering, energy laws characteristics, k-means method, masks, similarity criterions

Background and Significance

The modern systems of technical sight give the chance to automate various technological processes, such as automatic recognition of industrial parts, their sorting, dimension inspection, packing of products, control of their placement at technologies of welding, their space installation in the specified place and a great number of others [1 – 6].

The systems of technical sight function on the basis of processing of two-dimensional functions of images. Only partially displaying physical reality [1, 2], the image, nevertheless, bear very important information on the basis of which the majority of biological systems successfully functions, including the person.

The field of brightness (luminosity), in a general view non-uniform and non-stationary is a source of information on a condition of a visual field. In terms of visual perception this field in each element of space is defined by brightness, a color shade and saturation which can change over time.

The main objectives the system of technical sight when functioning robotic systems come down to localization of working space where there are objects which are looked for to allocation from a background and to pattern recognition of objects, measurement of direct and dynamic characteristics of different objects for their visual representation [1 – 4].

Current State of an Issue of Segmentation of Pattern Images

The battery of sensor nodes in the wireless sensor network In a broad sense segmentation is understood as allocation on the image of the objects which are of interest [1].

Segmentation is considered the first analysis stage of images, –it is the basic procedure practically in all problems of processing of images by means of the systems of computer sight. Segmentation renders importance on results of processing of images in general and is the perspective direction in the field of computer sight. As errors of segmentation lead to serious errors of postprocessing of images, for example, their normalization and recognitions, or do images not by the acceptable for further processing existing algorithms [8], therefore, as well as other problems of this area, a problem of segmentation cannot be completely formalized. Segmentation can include elements of filtration of hindrances, allocations of images, actually recognitions of images, the analysis of scenes.

Segmentation – one of key open problems of computer sight. Sometimes recognition and segmentation are not connected together, considering them as separate stages of processing of the image. Such point of view is considered unreasonable as at submission of the image in the form of a set of separate segments some specific problem is always solved [1, 8]. It is more than if it is possible to formulate precisely that should be distinguished, then it gives the chance to define what appearance will be had by segmentation. Therefore, the efficiency of universal methods of segmentation can often be enhanced considerably due to use of prior information, important for a specific problem.

The person separates the image into parts according to objects which interest him. Therefore, for segmentation it is possible to use classification which represents reference of objects to one of the fixed classes. Segmentation is a key question in computer sight as it gives the chance when comparing images to reject some information non-significant at the moment. For example, if the image of a tiger is looked for, then should not matter that is a background – snow or a grass as a key object is a tiger [7].

At the same time, if when comparing the image by means of calculation of a measure of similarity between the whole images which really include a background and other objects the image of a tiger on a grass significantly differs from a tiger on snow. From such observations there is a natural offer of segmentation of the image on the certain areas somewhat similar at each other. It is the most natural to consider that separate pixels, or calculations of characteristic in the fixed vicinities of these pixels are in harmony among themselves if they belong to the same object [7].

The mathematical model of a problem of segmentation has the following appearance: $D \rightarrow \{D_0,...,D_S\}$, where D – a raster the M×N size; $D_0,...,D_S$ – the areas of the image carried to S classes of equivalence respectively; {0...,S} – tags of classes of equivalence.

Various methods are applied to segmentation of images of various types. The most known and extended in practice methods of segmentation of images are [1, 8]: correlation, threshold, methods of the analysis of color, methods of building of areas, the methods based on allocation of borders, pattern methods.

Research of methods of segmentation of pattern images

The texture is the characteristic sign applied to segmentation of images on area of interest and to classification of these areas. The texture describes space distribution of colors or values of intensity on the image. One of tasks of the pattern analysis consists in exact definition of a concept of texture. Two main approaches are known.

Structural approach. The texture represents a set of the primitive teksel located in some regular or repeating order. Then the structural description of texture could consist of the description of teksel and their space interrelation.

Statistical approach. Instead of detection of teksel according to pixel data gray-scale (or color) images it is possible to calculate numerical characteristics of textures (pattern statisticians).

It is the best of all to consider the images consisting of a large number of small objects texture. As examples it is possible to call a grass, foliage of trees, gravel, wool, a bristle. Many surfaces are covered with the correct patterns which look as a large number of small objects: spots on a skin of animals; strips, as at a tiger or a zebra; patterns on bark of trees, wood and leather [5].

In figure 1 examples of various textures, natural and artificially created are given.

Figure 1: Examples of textures

The texture of the image usually includes the ordered patterns consisting of the correct elements (which sometimes call textons). The natural way of representation of texture is to find textons and to describe their arrangement. The lack of such description of texture is that there is no known initial set of textons, i.e. is not clear that should be looked for. Advantage of such method consists that it is easy to find simple elements of a pattern by means of filtration of the image.

Advantage of transformation of the image to new basis which gives its convolution with the filter consists that this process reveals structure of the image. It occurs thanks to the fact that reaction of the filter is stronger when the image pattern on any site is similar to a filter kernel, and weaklier otherwise. Thus, it is possible to present texture of the image in the form of reaction of set of filters. A set of various filters should consist of series of patterns – as a rule, spots and strips – at a certain sequence of scales. In spite of the fact that such approach is strongly superfluous, it gives an idea of structure (its "spottiness", "banding", etc.) which is very useful.

A particular interest for processing of images with pronounced texture has a method of Laws characteristics. Laws has developed power approach in which change of content of texture within a window of the fixed size is evaluated. In this method change of content of texture within a window of the fixed size is evaluated. For calculation of power characteristics set of sixteen masks is used by sizes 5x5. For receiving masks 4 vectors are used: the vector of L is intended for calculation of the symmetric weighed local mean, a vector E – for detection of edges, S — for detection of spots, a R — for detection of an image in the form of ripples.

On the first step in the Laws method it is offered to eliminate intensity of influence of lighting. For this purpose, according to the image the window (in this case the window of 15x15 in size has been chosen), in which of value of each pixel the local mean is subtracted moves. After processing each of 16 masks therefore 16 filtered images are formed is applied to the image. Further power pattern cards are under construction. Each pixel of the card is represented the sum of the pixels which are in area 15x15 around it. After obtaining 16 power maps some symmetric cards are combined and formed 9 final energy maps.

Thus, to each pixel there corresponds the vector from 9 pattern characteristics, and segmentation are carried out on the basis of comparison of these vectors of various fragments of the image.

Mathematical model of segmentation on a basis Laws characteristics

The method of power Laws characteristics assumes detection of various types of textures by means of local masks. By means of this approach change of content of texture within a window of the fixed size is evaluated. For calculation of power characteristics set of nine masks is used by sizes 5x5. Then power characteristics of each pixel of the analyzed image are presented in the vector form from 9 numbers. For calculation of masks the following vectors are used:

$L5 = [1\ 4\ 6\ 4\ 1]$; $E5 = [-1\ -2\ 0\ 2\ 1]$;

$S5 = [-1\ 0\ 2\ 0\ -1]$; $R5 = [1\ -4\ 6\ -4\ 1]$.

Two-dimensional masks are calculated by multiplication of couples of vectors.

Before calculation of power Laws characteristics, it is necessary to process the initial image previously. For this purpose, according to the image the small window moves and the local mean is subtracted from value of each pixel. Thus, influence of intensity of lighting is eliminated and the image on which the average intensity of each pixel vicinity is close to 0 is as a result formed. The size of a window depends on type of images. For natural scenes the window as the sizes 15 x 15 has been chosen.

After preparative treatment each of sixteen masks 5 x 5 is applied to the received image. Sixteen filtered images are as a result formed. Let's designate through $F_k[i, j]$ result of filtration of pixel [i, j] with use of k-y of a mask. Then power pattern card E_k for filter k is defined by expression: $E_k[r,c] = \sum_{j=c-7}^{c+7} \sum_{i=r-7}^{r+7} | F_k[i, j] |$. Thus, 16 pattern cards are formed.

After obtaining power maps some symmetric couples are combined and as a result nine final cards are under construction. Each symmetric steam of cards is replaced with the average card. After obtaining power characteristics they can be used for segmentation of pattern images.

For calculation of masks the vectors provided above are used. Names of vectors describe their assignment. The vector of L5 (level) is intended for calculation of the symmetric weighed local mean. The vector of E5 (edges) is intended for detection of edges, S5 (spots) — for detection of spots, a R5 (ripples) — for detection of an image in the form of ripples. [5] Two-dimensional masks are calculated by multiplication of couples of vectors, for example, for receiving L5R5 mask it is necessary to increase L5 vector column by R5 vector line:

$$\begin{vmatrix} 1 \\ 4 \\ 6 \\ 4 \\ 1 \end{vmatrix} * \begin{vmatrix} 1 & -4 & 6 & -4 & 1 \end{vmatrix} = \begin{vmatrix} 1 & -4 & 6 & -4 & 1 \\ 4 & -16 & 24 & -16 & 4 \\ 6 & -24 & 36 & -24 & 6 \\ 4 & -16 & 24 & -16 & 4 \\ 1 & -4 & 6 & -4 & 1 \end{vmatrix}$$

The sum of elements of all masks, except L5L5, is equal 0 therefore, according to Laws proposal, the result of application of this mask is used as the normalizing.

For obtaining the filtered image F_k by means of a mask M_k let's define convolution

$$F_k[l,s] = \sum_{i=-1}^{3} \sum_{j=-1}^{3} M_k[i+1, j+1] * B'[l+i-1, s+j-1],$$

where B' – the image after elimination of influence of intensity of lighting;

(l, s), (i, j) $\in D$; k $= \overline{1,16}$.

to receive and send the neighbor nodes energy message.

Creation of energy maps

Creation of energy maps is implemented by means of masks.

Let $F_k[i, j]$ – result of filtration of pixel [i, j] with use of k-y of a mask. Then power pattern card E_k for filter k is defined above. Each pattern power card is the full-size image which represents results of processing of the entrance image with use of k-y of a mask.

The orientation of textures is not so important for many problems of processing of pattern images. In this case similar features unite. For example, the EL5E5 card is sensitive to vertical edges, and EE5L5 is sensitive to horizontal edges. If to unite these pattern cards, we will receive one EL5E5T card sensitive to the maintenance of edges of both directions:

EL5E5T=(EL5E5+EE5L5)/2.

Similarly, we unite other similar pattern cards and we receive final 9 cards. Let's demonstrate each of them:

EL5E5T=(EL5E5+EE5L5)/2;

EL5S5T=(EL5S5+ES5L5)/2;

EL5R5T=(EL5R5+ER5L5)/2;

EE5S5T=(EE5S5+ES5E5)/2;

EE5R5T=(EE5R5+ER5E5)/2; ES5R5T=(ES5R5+ER5S5)/2;

EE5E5T=EE5E5;

ES5S5T=ES5S5;

ER5R5T=ER5R5.

Nine images of energy maps can be considered as one image in which to each pixel there corresponds the vector from 9 pattern attributes.

After calculation of energy maps boundary 7 pixels of the image are not considered in further processing because for them it is impossible to construct cards. This border in comparison with the size of the image is not essential.

Segmentation of images on the basis of power Laws characteristics

Segmentation is understood as process of splitting the image into textures of different classes.

The mathematical model of a problem of segmentation of images on the basis of Laws characteristics has the following appearance:

$$D \to \{D_1,...,D_S\},$$
$$D_r = \{(i,j) \mid Pr(\rho(\overline{E}(x_r, y_r), \overline{E}(i,j)) < \delta) = r\}, r = \overline{1,S},$$

where

$\overline{E}(x_r, y_r)$ –

vector $\overline{E}(x_r, y_r) = (E_1(x_r, y_r),\ldots,E_9(x_r, y_r))$ energy maps standards of class r;

area $D = \bigcup_{r=1}^{S} D_r$; $(i, j),(x_r, y_r) \in D / D_{r-1}$.

In this work pointwise segmentation which assumes creation of energy maps for all image has been considered. As a result, each pixel is characterized by a vector from 9 values which are used for an image segmenattion.

Making decision on accessory of two points to one class

At making decision on accessory of pixels of the image to one class of textures the following criterion was used:

$$\rho[\overline{E_0}, \overline{E_k}] < \delta,$$

where

δ – some threshold value which is set experimentally;

$\overline{E_0}$ – vector of energy maps of a standard of a class;

$\overline{E_k}$ – vector of energy maps of the current point;

ρ – a similarity measure which is calculated according to the chosen metrics.

For calculation of a measure of similarity it is possible to use a formula of the rated sum of a difference which has the following appearance:

$$\rho_{ij} = \frac{\sum_{k=1}^{9} | E_k^{ij} - E_k^{i'j'} |}{9}, (i,j) \in D,$$

where E_k^{ij} – value of pixel [i, j] on k-oh power card;

$E_k^{i'j'}$ – value of reference pixel on k-oh power card.

In classical methods of segmentation as a measure of similarity the Euclidean distance which is calculated as follows is most often used:

$$\rho_{ij'} = \sqrt{\sum_{k=1}^{9} (E_k^{ij} - E_k^{i'j'})^2}, (i, j) \in D,$$

Also, in this work as the metrics used for definition of a measure of similarity of pixels the classical coefficient of correlation was used:

$$\rho_{ij} = \frac{\sum_{i=1}^{9} E_k^{ij} E_k^{i'j'}}{\sqrt{\sum_{i=1}^{9} (E_k^{ij})^2 \sum_{i=1}^{9} (E_k^{i'j'})^2}}, (i, j) \in D$$

Application of a k-means method for initial splitting into classes

Application of a method of power Laws characteristics at the solution of a problem of segmentation of images with pronounced texture allows to allocate contours accurately.

The received results can be improved, having used for specification of classes a k-means method, belonging to the section of a clustering.

The clustering is an automatic splitting elements of some set (objects, data, a vector of characteristics) on groups (clusters) on the principle of similarity.

The purpose of a clustering is creation of optimum splitting objects into groups. The optimality can be defined as the requirement of minimization of a mean square error of splitting which has the following appearance:

$$e^2(X, L) = \sum_{j=1}^{k} \sum_{i=1}^{n_1} \left\| x_i^{(j)} - c_j \right\|^2$$

where

> k – quantity of the classes received as a result of pointwise segmentation by method of power Laws characteristics and demanding specification;
>
> n_1 – quantity of the points belonging to the current class;
>
> $x_i^{(j)}$ – class j-go element;
>
> c_j – reference j-go element of a class.

Algorithm of k-averages (k-means clustering) — very fast, simple and rather exact method of a clustering of objects. To define quantity of clusters of splitting, it is necessary to make segmentation of the image by method of power Laws characteristics. Further for each cluster the representative as an arithmetic average from all elements of this class is defined. The received standards are the initial "centers of masses" of clusters. Let's give a formula of calculation of a reference element:

$$M_j = \frac{\sum_{i=1}^{N_1} x_i}{N_1}, \; j = \overline{1,k}$$

where

M_j – the representative of j-go of a class;

x_i – the class j-go elements.

The formula is applied to calculation of 9 power characteristics of the representative of a class. Thus, the reference element represents a vector from nine values.

At the following stage it is necessary to carry each object to a cluster with the next "center of masses". For this purpose, distances from each point of the image to each representative from M_j are calculated, according to one of the metrics considered above. Formulas for calculations of distances are similar to formulas of definition of a measure of similarity. An object belongs to that cluster to which distance is minimum.

After redistribution of points of the image recalculation of "the centers of masses" of clusters according to the current membership is made. Criterion of a stop of iterative process is the minimum change of a mean square error of splitting which is provided above, or lack of transition of objects from a cluster to a cluster.

When results of the cluster analysis by method k - averages are received, it is possible to calculate averages for each cluster on each measurement to evaluate as far as clusters differ from each other. Ideally strongly differing averages for the majority turn out if not for all measurements used in the analysis.

The considered technique allows to allocate contours so accurately that the form of the segmented objects is as close as possible to real.

Development of an algorithm of segmentation by method of consecutive search on the basis of power Laws characteristics

The segmentation algorithm by method of consecutive search has the following appearance:

Step 1: Input of the image N×N size.

Step 2: We build energy maps of the entrance image

Step 3: We enter the counter of tags of i = 0.

Step 4: We appropriate to the first pixel of the image a tag of i+1 and we consider it reference for (i+1) - go a class.

Step 5: We calculate similarity coefficients ρ_{ij} for reference pixel and all not marked image points. If the similarity coefficient ρ is less than set threshold δ, then we mark this point with a tag of a class of reference pixel. We pass on all points of the image.

Step 6: We repeat steps 4 and 5 so far all points of the image will not be marked

Step 7: We paint over the received classes on the image in pseudo-flowers.

Results of segmentation with use of various measures of similarity

The made experiments have shown expediency of use of a method of power Laws characteristics for the description of pattern images.

Results demonstrate that the segmentation algorithms by Laws method developed in this thesis are sensitive to change of a threshold and a technique of calculation of a measure of similarity between pixels. The example of segmentation of the image with use of various measures of similarity is given in figure 2.

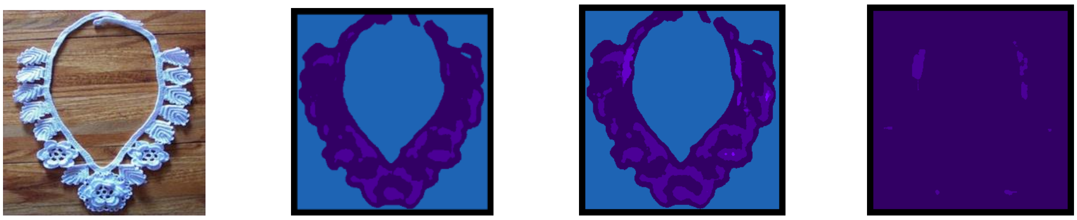

Figure 2: Using different measures of similarity

When using various measures of similarity of value of an indicator ρ change in the different ranges. For a research of sensitivity of the developed algorithms to change of a threshold taking into account various formulas of calculation of a measure of similarity, normalization on has been carried out. As a result, irrespective of a technique of definition of a measure of similarity the threshold changes in the range from 0 to 1.

The made experiments have shown that the threshold 0.3 for segmentation of test images is the best since at a threshold higher than 0.3 texture are distinguished indistinctly, and at a threshold lower than 0.3 at the outlet too many classes turn out (figure 3).

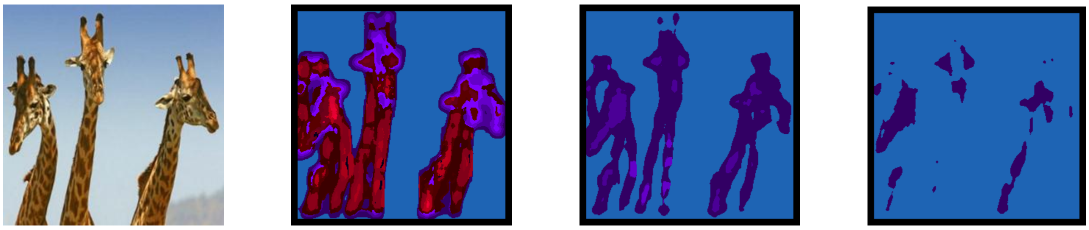

Figure 3: Using different threshold value

Conclusion

As a result of implementation of the thesis have been developed and algorithms of segmentation of pattern images on the basis of power Laws characteristics are by software realized and their practical researches are conducted.

The analysis of the carried-out work has shown expediency of use of power Laws characteristics in a problem of segmentation of images with pronounced texture. Also it is necessary to notice that application of a method to - averages for the purpose of specification of segmentation allows to allocate contours more accurately and as much as possible to bring closer a form of the segmented objects to real.

The results received at allocation of pattern objects by the user can be used for the solution of other tasks connected with processing of images, for example, for problems of recognition or as templates for search in databases.

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