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EXPLORATION OF STABILITY FOR SEGMENTATION METHOD BASED ON WAVE REGION GROWING

O.M. ALMIAHI

Belarusian State University of Informatics and Radio Electronics
P. Brovki, 6, Minsk, 220013, Belarus

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A method of progressive segmentation of gray scale images based on wave quasi parallel region growing is proposed. In contrast to known methods of segmentation of the proposed method allows to divide the area with smoothing drops of brightness and adapt to the constraints time of segmentation.

Keywords: *image segmentation, region growing.*

Introduction

The Image segmentation is widely applied in solving various tasks of video information processing. Image segmentation is defined as the process of partitioning the digital image into different sub regions of homogeneity. Each of the pixels in a region is similar with respect to some characteristic or computed property, such as color, intensity, or texture. The result of image segmentation is a collection of segments which combine to form the entire image [1].

The efficiency of image segmentation depends on standard conditions, such as the kind of feature information used for grouping, the credibility of feature extraction and merging of feature information [2, 3]. In some cases, the segmentation time may be limited. It is also possible the task of image segmentation with smoothing drops of brightness. The known segmentation methods based on the formation of regions using a watershed [4], quantization of an histogram [5], split and merge regions using Quadra-tree [6, 7], region growing [8, 9], are not effective under these conditions. Segmentation using the watershed does not provide excretion for the smooth drops of brightness of images. Segmentation based on quantization of an histogram does not provide an accurate separation of regions because of assigning the same segment number with the same brightness. Methods based on the separation and merging regions using Quadra-tree and based on growing regions [10, 11] can accurately image segmentation, but also does not allow to find the boundaries of the regions on the smooth drops of brightness, which results in a segmentation fault. In addition, all the considered methods do not provide the adaptation to a limitation on the time of segmentation. In this regard, is relevant task of developing a method of image segmentation, which takes into account these shortcomings.

The aim is to develop a method of image segmentation, which allows to separate the regions with smooth drops of brightness and adapt to the limitations of time of segmentation.

Method of image segmentation based on the wave region growing

For the progressive segmentation of halftone images, a method based on the wave quasi-parallel growing regions is proposed. The essence of the method is a quasi-parallel region growing around the chosen initial points of growth that provides automatic separation of the regions with smooth drop of brightness, that the known methods segmenting with errors.

Algorithm of Image segmentation based on the wave region growing consists of the following steps.

Step 1. Initialization. In this step is carried out buffering of image $I = \|i(y,x)\|_{\left(y=\overline{0,Y-1},x=\overline{0,X-1}\right)}$ which have size YX pixels and threshold detection $\Delta_G = f(I)$, determines the conditions of accession of the pixel to the grown of the region. To select the threshold Δ_G can be used the histogram of first derivatives of pixel values in rows and columns. Forming a zero matrix of segmentation $SM = \|sm(y,x)\|_{\left(y=\overline{0,Y-1},x=\overline{0,X-1}\right)}$, elements which determines as following equation:

$$sm(y,x) \Leftarrow 0, \tag{1}$$

where $y = \overline{0,Y-1}$, $x = \overline{0,X-1}$.

The counter of segmented values C_{SM} is assigned a value 0: $C_{SM} \Leftarrow 0$. Initialized zero stack of collision $CM_Y = \|cm_Y(z)\|_{\left(z=\overline{0,Z_{CM}-1}\right)}$ and $CM_X = \|cm_X(z)\|_{\left(z=\overline{0,Z_{CM}-1}\right)}$, where $cm_Y(z) \Leftarrow 0$, $cm_X(z) \Leftarrow 0$, where $z = \overline{0,Z_{CM}-1}$, Z_{CM} – maximum number of elements in the stack. Pointer stack of collision stopping on 0, $z = 0$.

Step 2. Start cycle of segmentation, choosing initial points for growth of regions from the stack. For example local maximum of histogram pixels values of image, which correspond to the zero values in the matrix of segmentation can be used. Let matrices $BM_Y = \|bm_Y(k)\|_{\left(k=\overline{0,K_{BM}-1}\right)}$, $BM_X = \|bm_X(k)\|_{\left(k=\overline{0,K_{BM}-1}\right)}$ contain coordinates of initial points of growth, where K_{BM} – number of initial points of growth.

Step 3. Initialization stacks $\{GM_Y(k)\}_{\left(p=\overline{0,K_{BM}-1}\right)}$, $\{GM_X(k)\}_{\left(p=\overline{0,K_{BM}-1}\right)}$ for growth of regions, $GM_Y(k) = \|gm_Y(k,p(k))\|_{\left(p(k)=\overline{0,P_{GM}(k)-1}\right)}$, $GM_X(k) = \|gm_X(k,p(k))\|_{\left(p(k)=\overline{0,P_{GM}(k)-1}\right)}$.

The pointer of every stack of growth of region is set to 1: $p(k) \Leftarrow 1$ where $k = \overline{0,K_{BM}-1}$. The counter C_{SM} of segmented value is assigned to the number of initial points of growth: $C_{SM} \Leftarrow K_{BM}$. Elements of matrix of segmentation, the coordinates which correspond to the coordinates of the initial points of growth are assigned numbers of segments (each element is assigned a number of previously unused):

$$sm\left(bm_Y(k), bm_X(k)\right) \Leftarrow (k+1), \tag{2}$$

where $k = \overline{0,K_{BM}-1}$.

Step 4. Initialization counter of cycles of busting regions are grown (set to zero), $k \Leftarrow 0$.

Step 5. Start cycle of busting grown of regions, from stack of the growth of the regions, the number which corresponds to the counter value of cycle busting of grown regions, are extracted coordinates of the current grown pixel, which indicates a value corresponding to the stack pointer. The value of the stack pointer decreases by one:

$$y_B \Leftarrow gm_Y(k, p(k)), \tag{3}$$

$$x_B \Leftarrow gm_X(k, p(k)), \tag{4}$$

$$p(k) \Leftarrow p(k) - 1. \tag{5}$$

Step 6. Initialization the counter of surrounding pixels $l \Leftarrow 0$.

Step 7. Start the analysis cycle of the surrounding pixels.

Step 8. Checking to zero the value of element of the matrix of segmentation, the coordinates which correspond to the found coordinates (y_A, x_A) of the surrounding pixel. If this value is not equal to zero ($sm(y_A, x_A) \neq 0$), then go to the step 13, else ($sm(y_A, x_A) = 0$) – go to the next step.

Step 9. The absolute value of the difference values of the current grown pixel $i(y_B, x_B)$ and the current surrounding pixel $i(y_A, x_A)$ is compared with a given threshold Δ_G. If the absolute value of the difference is less than the threshold ($\left|i(y_B, x_B) - i(y_A, x_A)\right| < \Delta_G$ the surrounding pixels must be joined to the region), then go to the next step, otherwise ($\left|i(y_B, x_B) - i(y_A, x_A)\right| \geq \Delta_G$) go to step 16.

Step 10. Elements of the matrix of segmentation, which coordinates correspond to the coordinates (y_A, x_A) of the current surrounding pixel, assigned a value of element of segmentation matrix, which coordinates are correspond to the coordinates (y_B, x_B) of the current grown pixel

$$sm(y_A, x_A) \Leftarrow sm(y_B, x_B). \quad (6)$$

Step 11. Pointer the current stack of the growth region is incremented by one. In the current stack of the growth region are brought coordinates (y_A, x_A) of the current surrounding pixel:

$$gm_Y(k, p(k)) \Leftarrow y_A, \quad (7)$$

$$gm_X(k, p(k)) \Leftarrow x_A, \quad (8)$$

$$p(k) \Leftarrow p(k) + 1. \quad (9)$$

Step 12. Value counter C_{SM} of segmented values is incremented by 1: $C_{SM} \Leftarrow C_{SM} + 1$ – go to the step 16.

Step 13. Checking the collision. Compares the value of elements of segmentation, the coordinates which correspond to the coordinates (y_A, x_A) of the current surrounding pixel and (y_B, x_B) the current grown pixel. If these values are equal ($sm(y_A, x_A) = sm(y_B, x_B)$), then go to the step 16, else $(sm(y_A, x_A) \neq sm(y_B, x_B))$) – go to the next step.

Step 14. The absolute value of the difference the pixel values of the image, coordinates which correspond to the coordinates (y_B, x_B) of the current grown pixel and (y_A, x_A) the current surrounding pixel are compared with the given threshold Δ_G. The absolute value of the difference of values of pixels in the image, the coordinates which correspond to the coordinates $(bm_Y(k), bm_X(k))$ and $(bm_Y(s), bm_X(s))$ of the initial points of growth for the considered segments *k* and *s*, are also compared with given threshold Δ_G. If the absolute value of the difference less than the threshold $\left(\left|i(y_B, x_B) - i(y_A, x_A)\right| < \Delta_G\right) \vee \left(\left|i(bm_Y(k), bm_X(k)) - i(bm_Y(s), bm_X(s))\right| < \Delta_G\right)$ – surrounding pixel must be joined to the current region, but already joining to other region – having allocation of collision), then go to the next step, else – go to the step 16.

Step 15. The current element of the stack of collisions are assigned to coordinates of the current surrounding pixel and the current growing pixel, the stack pointer of collisions twice incremented by one:

$$cm_Y(z) \Leftarrow y_B, \; cm_X(z) \Leftarrow x_B, \; z \Leftarrow z + 1, \quad (10)$$

$$cm_Y(z) \Leftarrow y_A, \; cm_A(z) \Leftarrow x_B, \; z \Leftarrow z + 1. \quad (11)$$

Step 16. Ending cycle of analysis of the surrounding pixels. Counter surrounding pixels is incremented by 1: $l \Leftarrow l + 1$. Checking inequality the counter value of the surrounding pixels and the number of neighboring pixels (8 pixels). If the counter of the surrounding pixels is less than 8 ($l < 8$), then skip to step 7, else ($l = 8$) – out of the cycle.

Step 17. Ending cycle busting growing of regions. The counter cycle busting of growing regions increased by one: $k \Leftarrow k + 1$. Checking inequality the counter value of the cycle busting of growing regions and number of initial growth points. If the counter of cycle busting growing regions less than number K_{BM} of initial growth points. If the counter of cycle busting growing regions less than number of initial points of growth ($k < K_{BM}$), then skip to step 5, ($k \geq K_{BM}$) – out of the cycle.

Step 18. Ending the cycle of segmentation. If the counter C_{SM} of segmented values equal to number pixels of image ($C_{SM} = YX$), then out of the cycle (formed an intermediate matrix of segmentation), else ($C_{SM} \neq YX$) – go to step 2.

Step 19. Initialized resulting matrix $SM_R = \left\| sm_R(y,x) \right\|_{\left(y=\overline{0,Y-1},\, x=\overline{0,X-1}\right)}$ of segmentation. Values matrix of segmentation are brought in result matrix of segmentation:

$$sm_R(y,x) \Leftarrow sm(y,x), \tag{12}$$

where $y = \overline{0,Y-1}$, $x = \overline{0,X-1}$.

Step 20. Checking the stack pointer of collision as 0. If the pointer equal to zero $z = 0$, then skip and out from the algorithm, else ($z \neq 0$) – go to the next step.

Step 21. Resolving collisions. In stack of collisions are found associated segment numbers, which are assigned new numbers. These numbers are brought in result matrix of segmentation. The stack pointer of collision is decreases by the corresponding number. When the stack pointer of collision equal to zero, skip for out of algorithm.

As a result of executing this algorithm is formed matrix of segmentation, value of each element which indicates a segment number, which belongs to the segmented pixel of image with corresponding to coordinates. With each cycle of busting growing of regions, the size of the segments gradually increasing, in what appears the progressive character of segmentation implemented by the proposed method. In the case of interruption (e.g. when searching for small objects) algorithm part of the image will remain un-segmented, however, will find all the dominant centers of regions and these regions will be uniformly segmented.

Evaluating the effectiveness of segmentation algorithms

The stability of the number of segments to change the image forming conditions is the main advantage of the proposed method of segmentation. The proposed method is implemented in MATLAB 2012. The experiment was performed on a computer with the following specifications: Processor – AMD A8-5600U APU – 3.60 GHz; RAM – 4 GB; type of system – 32-bit operating system Windows 7.

In Fig. 1 the results of segmentation for standard test image France 2048 using suggested method and method of segmentation based on region growing are shown.

а *б* *в*

Fig. 1. Results of segmentation for standard test image France:
a – test image; *b* – result for proposed method; *c*) region growing

An assessment of the effectiveness of the proposed method of progressive segmentation based on wave quasi parallel of region growing and known methods of segmentation based on region growing, split and merge areas, watershed. As performance indicators used the time of segmentation, the stability of borders and the number of segments.

In table. presents the results of evaluation of the time of segmentation for considered methods. From table. Follows, that the proposed method wins in the speed of segmentation to 4 times and 40 times in comparison with the segmentation methods based on region growing and split and merge regions with an image size of 128×128 pixels, losing in speed of segmentation to 5 ones when size 512×512; 2,5 ones when size 1024×1024 with method of segmentation based on region growing.

Segmentation time for test images, s

Methods of segmentation	**Time of Segmentation for tested images**			
	Boat 128	Lena 256	Barbara 512	France 8
Suggested method	**0,111867**	**0,7586**	**5,8029**	**88,6354**
Region growing	**0,439241**	**0,5269**	**0,8005**	**35,9598**
Splitting and merging regions	**4,3641**	–	–	–

In Fig. 2 shows the dependence of the areas of segments by changing the brightness, contrast, and image rotation, characterizing sustainability boundaries of segments. Stability is evaluated by the area ratio of segments for the base image to the area of the segments for the modified image, subject to change brightness, contrast and angle of rotation. From Fig. 3 follows, that suggested method losing in the stability of areas of segments to 7; 6; 6 ones when changing brightness, contrast and angle of rotation respectively in comparing with method of segmentation based on region growing. suggested method by comparing with the segmentation method based on splitting and merging regions losing in the stability of areas of segments to 3; 3,5 ones when changing brightness and contrast, but wins in the stability of areas of segments to 2,7 ones when changing the angle of rotation, results below is calculated on standard test images Lena 128×128 and water 128×128 respectively.

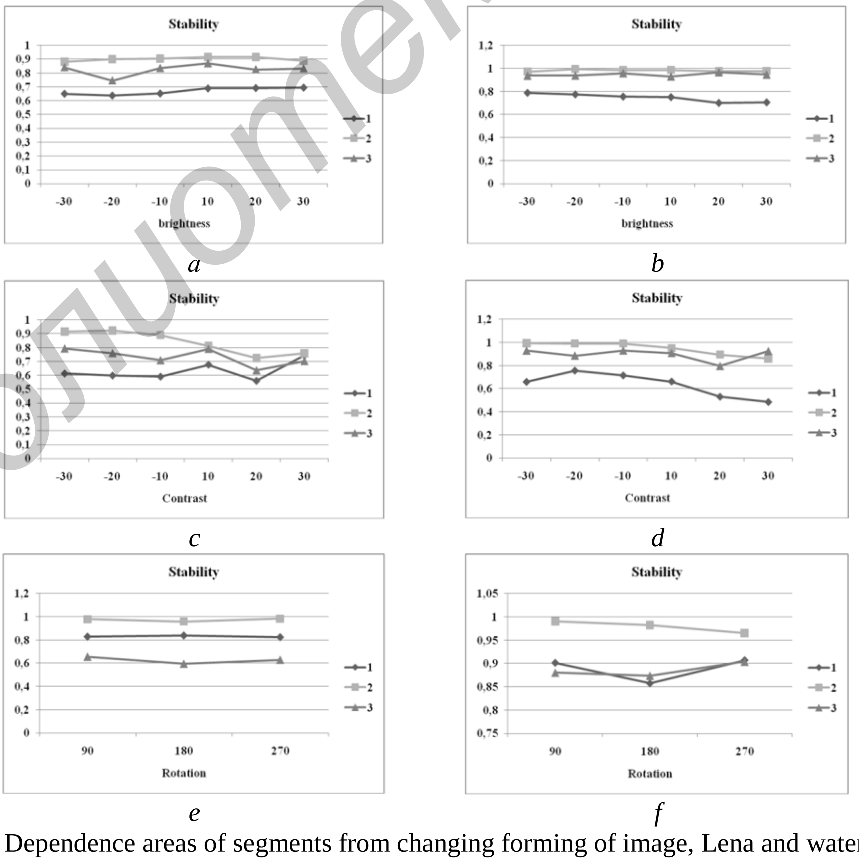

Fig. 2. Dependence areas of segments from changing forming of image, Lena and water (1 – suggested method; 2 – region growing; 3 – splitting and merging regions): *a, b* – when changing the brightness; *c, d* – when changing the contrast; *e, f* – when changing the angle of rotation

In Fig. 3 it is shown the dependence number of segments from changing the brightness, contrast, and image rotation, characterizing sustainability results of segments. Stability is evaluated by ratio of the number of segments for the base image to the number of segments for the modified image, subject to change brightness, contrast and angle of rotation. From Fig. 4 follows, that proposed method winning in stability of number of segments to 3,6; 4,5 and 3 ones when changing in brightness, contrast and angle of rotation in comparing with method of segmentation based on region growing. suggested method by comparing with the segmentation method based on splitting and merging regions winning in the stability of number of segments to 4,5; 4,4 and 7 ones when changing in brightness, contrast and angle of rotation of image respectively.

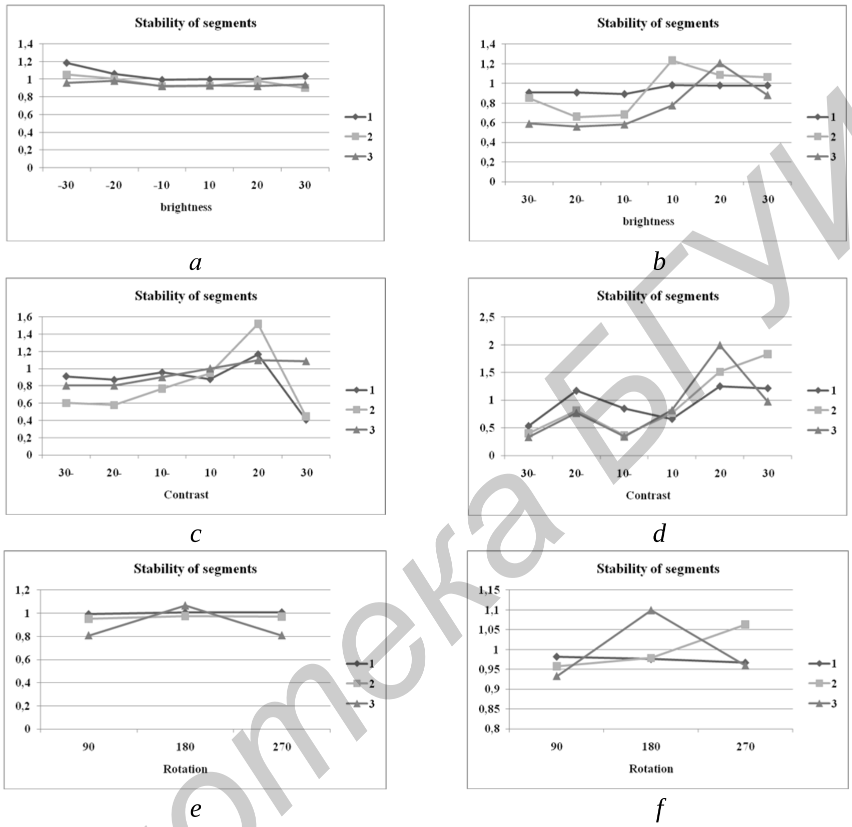

Fig. 3. Dependence number of segments from changing forming of image, Lena and water (1 – suggested method; 2 – region growing; 3 – splitting and merging regions): *a*, *b* – when changing the brightness; *c*, *d* – when changing the contrast; *e*, *f* – when changing the angle of rotation

Summary

For the progressive segmentation of halftone images proposed a method based on the wave quasi parallel region growing. The essence of the method is a quasi-parallel growing areas around the chosen initial points of growth, that provides automatic separation of areas with a smooth drop of brightness, which known methods segmenting with errors. Showing, that proposed method provides increased sensitivity of segmentation to drops in brightness 1,6 % in comparing with method of segmentation based on region growing and 10,9 % in comparing with method of splitting and merging of regions. Established, that the proposed method losing in the stability areas of segments to 7; 6 and 6 ones when changing brightness, contrast and angle of rotation respectively in comparing with method of segmentation based on region growing. By comparing with segmentation method of splitting and merging regions, the proposed method losing in the stability of areas of segments to 3; 3,5 ones when changing brightness and contrast, but wins in the stability of areas of segments to 2,7 ones when changing the angle of rotation. Proposed method winning in stability of number of segments to 3,6; 4,5 and 3 ones when changing in brightness, contrast and angle of rotation in comparing with method of segmentation based on region growing. Suggested method by comparing with the segmentation method based on splitting and merging regions winning in the stability of number of segments to 4,5;

4,4 and 7 ones when changing in brightness, contrast and angle of rotation of image respectively. Established, that the proposed method winning in the speed of segmentation to 4 and 40 ones in comparing with method of segmentation based on region growing and method of splitting and merging regions when size of image 128×128 pixels.

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