Quality Analysis of Image Segmentation based on G-UN-MMS

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***Abstract* — We analyze the quality of segmentation of the simple segmentation algorithm based on G-UN-MM representation method introduced in other papers; then, we compare the segmentation results according to the G-UN-MMs with those obtained by other algorithms. We briefly present a preliminary report on the comparison of segmentation methods using only two objective comparison indices. Results that are more detailed will be presented in a definitive paper to extend this preliminary one.**

***Index Terms* —image segmentation, G-UN-MM models, segmentation quality, unsupervised evaluation**

I. INTRODUCTION

Image segmentation is the separation/delineation of objects between them and against background. There is a lot of segmentation methods in literature such as: region-growing [1], [2], split and merge [3], clustering method: k-means, fuzzy C-means [4], edge-based segmentation [5] thresholding [6], [7] as well as other segmentation methods [8] based on combination of the above. Therefore, the quality of segmentation, the similarity of the results with segmentation by human operators should be evaluated. Quality can be determined subjectively by human assessors, or objectively, by computer using quantitative indicators (factors). When comparing methods by the machine, the empirical factors are modeling the quality assessment made by the experts.

Carrying out an unsupervised segmentation means excluding the human factor and using metrics indicating the quality of segmentation. One metric of quality is precision boundary object / objects against the background. A difficult case is, for example, the delineation of small objects (coffee beans, peas, etc.) that could be considered texture.

Of concern in segmentation is the accuracy of the segment assessment – checking whether the segment is equal to the surface area of the object in the image area; for example, reflections of light and shadows are often determined as separate segments.

Yet another characteristic evaluated for segmentation algorithms is the computational complexity (computational complexity of time and space).

II. UNSUPERVISED EVALUATION OF SEGMENTATION METHOD

When making supervised evaluation, the segmentation results are compared with those of stereotyped ones provided by experts in the field: the experts are drawing the outline of objects, manually delimiting the area of interest to be further processed. In case of unsupervised evaluation, several evaluation metrics were proposed for assessing the homogeneity of the regions, the difference of the mean value between regions, the contrast between object and the background region, to decide if too many or too few segments are obtained and others [9], [10], [11]. An important factor in evaluating the quality of segmentation is the texture. Test images for this work do not contain textures, but the texture-based segmentation is widely used [12]; moreover, texture features combined with other methods improve the determination of texture regions [13].

In order to decide if an over-segmentation has occurred, i.e. if there are more segments than actually objects in the image, J. Liu and Y.-H. Yang [14] have proposed the following function:

$$F(I) = \sqrt{N}\sum_{j=1}^{N}\frac{e_j^2}{\sqrt{S_j}} \tag{1}$$

where I is the segmented image, N is number of obtained regions after segmentation, S_j – area of region j and e_j^2 – squared color error (or the gray level) that is calculated as

$$e_j^2 = \sum_{k\in S_j}(x_k - \bar{x})^2 \tag{2}$$

where x_k is the gray level of the pixel, and the $\bar{x}$ means gray level of the region. Therefore e_j^2 shows the scattering of the gray values of pixels on a surface. In order to calculate the correct variance, it is required to include in the computation the surface area (total number of pixels in the region S_j) the gray values are distributed on. For regions with an uniformly distributed gray value, we obtain $e_j^2 = 0$.

III. SEGMENTATION ALGORITHM BASED ON G-UN-MMS

The segmentation methods based on histogram usually determine the thresholds as being the minimum values of the histogram – the "valleys" of Gaussian distribution. We, HN.Teodorescu and I, have proposed a novel way of using the global statistics of gray images for image segmentation. [15]. The statistics $p(G)$, where G is the gray level, is empirically represented by the histogram, $n(G)$. In the distribution function, instead of finding the "valleys" or approximating it with a set of Gauss functions, as in other methods, we identify the intervals of almost constant probability. These are the intervals X_k satisfying one of the sets of conditions $\forall x_1, x_2 \in X_k \quad | p(x_1) - p(x_2) | < \delta$ and $length(X_k) > \lambda G_{\max}$, $0 < \lambda < 1$, with δ and λ predetermined parameters of the procedure, or $\forall x_1, x_2 \in X_k \quad STDV(X_k) < \delta$ and the second condition identical to the above. Once the intervals X_k are determined, the partition of the gray interval $[0, G_{\max}]$ is completed with the remaining intervals. The segments of the image $G(i, j)$ are determined according to the intervals X_k so determined. By varying the parameters δ and λ, several segmentation results can be obtained.

a. peppers b. Lena

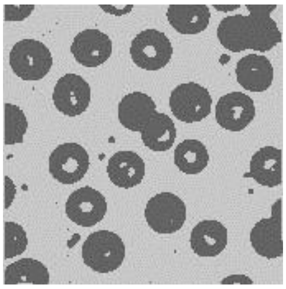
Fig. 1 Typical test images: *peppers* [16] and *Lena* [17]

IV. RESULTS

The results achieved on test images *"peppers"* and *"Lena"* from [16] respectively [17] that we used in our previous works [15] and [18] are given in Table I. For comparing the results, we have chosen the Otsu standard method [20], which is also a segmentation method based on histogram.

For the test images *blood cells* [21] and *rice* [22] we compute the *inter-region disparity metric* σ_B^2 [23].

TABLE I. SEGMENTED IMAGES WITH THE PROPOSED METHOD AND OTSU'S METHOD (WITH 2 THRESHOLDS), DISPERSIONS VALUES FOR SEGMENTS AND ORIGINAL IMAGES, FUNCTION F

Segmented image with **proposed method**			
			
S_1=22.24 S_1/S_{im}=0.41 S_2=6.95 S_2/S_{im}=0.13 S_3=23.87 S_3/S_{im}=0.44 Simage=54.31 **F=216 562**	S_1=25.92 S_1/S_{im}=0.57 S_2=6.98 S_2/S_{im}=0.15 S_3=20.94 S_3/S_{im}=0.46 Simage=45.73 **F=215 677**	S_1=34.70 S_1/S_{im}= 0.72 S_2=10.94 S_2/S_{im}=0.23 Simage=48.26 **F=241 308** $\sigma_B^2 = $ **1825**	S1=7.61 S1/Sim=0.14 S2=42.51 S2/Sim=0.78 Simage=54.32 **F=337 360** σ_B^2 **=2425**
Segmented image with **Otsu's method**			
			
S_1=21.44 S_1/S_{im}= 0.40 S_2= 17.63 S_2/S_{im}=0.32 S_3=19.08 S_3/S_{im}=0.35 **F=195 039**	S_1=12.16 S_1/S_{im}=0.27 S_2=18.06 S_2/S_{im}=0.40 S_3=21.29 S_3/S_{im}=0.47 **F=161 258**	S_1=14.08 S_1/S_{im}=0.30 S_2=22.10 S_2/S_{im}=0.46 **F=154 203** σ_B^2 **=1916**	S1=17.05 S_1/S_{im}= 0.31 S2=32.34 S_2/S_{im}=0.60 **F= 234 402** σ_B^2 **=2518**

Here, s1, s2 and s3 represent the gray values of the segments, S_1, S_2, S_3 - the dispersion of the segments. The segmented images by Otsu method were obtained by us using the algorithm from [20].

One of the metrics for evaluating the quality of binary images segmentation is inter-region disparity:

$$\sigma_B^2 = \frac{S_B}{S_I} \cdot \frac{S_O}{S_I} \cdot (\overline{x}_{k(O)} - \overline{x}_{k(B)})^2 \qquad (3)$$

where S_B is the areas of the background and S_O - the area of the object, $\overline{x}_{k(O)}$ and $\overline{x}_{k(B)}$ represent the average values of the gray-level of the object and respectively of background.

The proposed algorithm [15] for histogram segmentation uses at least two thresholds (the limits of the largest quasi constant interval on the histogram). For obtaining a segmented binary image was chosen for "*blood cells*" the right limit as threshold (Th2) and for "*rice*" - the left (Th1). Otsu algorithm provides the number of obtained classes at beginning (1 ... n), and finds k thresholds for effective segmentation based on determining a smaller dispersion within the classes.

Evaluation of a segmentation method can be performed by comparing the results with those achieved by using standard segmentation algorithms (reference algorithms). We chosed to compare the achieved results with K-Means clustering segmentation method, as described in [19] and one of the versions of Otsu method, as described in [20].

Notice that the gray value we used for the segments are not necessarily identical with those used in the literature for the same images. The function F and the inter-region disparity metric σ_B^2 are calculated on the gray-level of the original images. The gray-level of the represented segments has no influence on the obtained results.

In order to make a comparison of the results of *peppers* color image segmentation [24] by using the proposed method with other methods from the literature, we take into account primarily the number of obtained segments. Using different comparison values in the G-UN-MM algorithm for determining the constant intervals upon the color image segmentation (the application of segmentation algorithm on each array separately: Red, Green and Blue) we have got different numbers of segments, as in Table III.

TABLE II. NUMBER OF OBTAINED SEGMENTS

Comparison value for determining the threshold	Number of segments
p=1.5	3
p=3.5	6
p=5.0	8

For comparing the results we chose the representation of obtained segments surfaces intersections: the proposed method with K-mean, the proposed method with Otsu and, finally, K-mean with Otsu.

TABLE III. SURFACES OF OBTAINED SEGMENTS

The method applied on image 'peppers.jpg' 410x410 pixels	Area in **pixels** and **%**					
	Segment 1		Segment 2		Segment3	
Color-Based Segmentation Using K-Means Clustering	48 470	28.83%	83 840	49.88%	35 790	21.29%
Image segmentation using Otsu thresholding	60 289	35.86%	77 303	45.99%	30 508	18.15%
Segmented Image with proposed method **p=1.5**	75 963	45.19%	88 633	52.73%	3 504	2.08%

TABLE IV INTERSECTION OF AREAS OF SEGMENTS

The method applied on image 'peppers.jpg' 410x410 pixels	**Intersection of areas of segments Segmented Image with proposed method p=1.5**					
	Segment 1		**Segment 2**		**Segment 3**	
Our Methods AND Color-Based Segmentation Using **K-Means** Clustering	48102 28.61%	our 75 963 45.19%	81220 48.32%	our 88 633 52.73%	3473 2.06%	our 3 504 2.08%
		kmeans 48 470 28.83%		kmeans 83 840 49.88%		kmeans 35 790 21.29%
Our Methods AND Image segmentation using **Otsu** thresholding	48773 29.01%	our 75 963 45.19%	77134 45.89%	our 88 633 52.73%	3487 2.07%	our 3 504 2.08%
		otsu 60 289 35.86%		otsu 77 303 45.99%		otsu 30 508 18.15%
K-Means Clustering AND Otsu thresholding	36 296 21.59%	kmeans 48 470 28.83%	70 872 46.16%	kmeans 83 840 49.88%	18 561 11.04%	kmeans 35 790 21.29%
		otsu 60 289 35.86%		otsu 77 303 45.99%		otsu 30 508 18.15%

In Table IV the areas of the segments are in pixels. The values in % represent the number of pixels of the intersection of the corresponding segments vs. $100 \cdot \frac{\text{Nr. of pixels intersection}}{\text{Total Nr. of pixels in the image}}$. For each segment, the first sub-column represents the area (in pixels) of the intersection of the segment obtained with the G-UN-MM method with the corresponding segment obtained by the alternative method.

The intersection of areas of segments obtained with the proposed method and other methods: A∩B=50 (black - color value 50), A-B=100 (gray – color value 100), B-A=200 (gray – color value 200), where A denotes segments obtained with proposed method, B - segments obtained using K-Means (a), respectively using Otsu thresholding (b)

TABLE V INTERSECTION OF AREAS OF OBTAINED SEGMENTS WITH PROPOSED METHOD AND K-MEANS CLUSTERING, OTSU'S METHOD

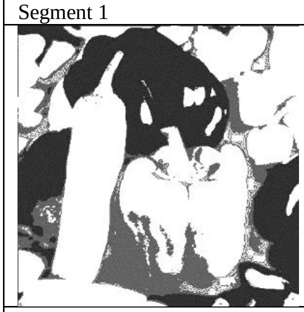
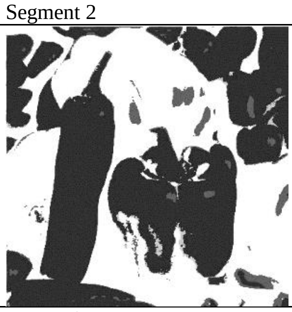
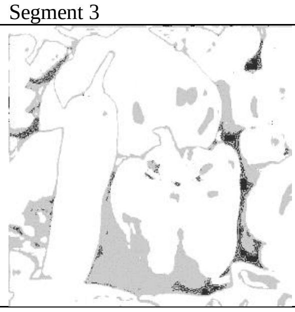
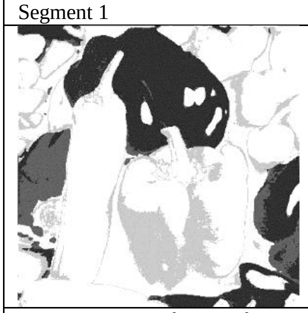
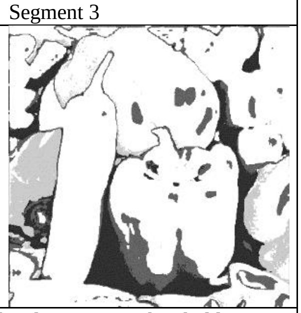
Segment 1	Segment 2	Segment 3
		
a. Intersection of areas of segments for Color-Based Segmentation using K-Means Clustering method		
		
b. Intersection of areas of segments for Image segmentation using Otsu thresholding method		

TABLE VI INTERSECTION OF AREAS OF OBTAINED SEGMENTS WITH K-MEANS CLUSTERING AND OTSU-S METHOD

Segment 1	Segment 2	Segment 3
		
Intersection of areas of segments using K-Means Clustering method and using Otsu thresholding		

The intersection of areas of segments of segmented image with proposed method and other methods: $A \cap B=50$ (black - color value 50), A-B=100 (gray- color value 100), B-A=200 (gray- color value 200), where A denotes segments obtained from a specified image using K-Means and B denotes the same segments obtained from the same specified image using Otsu thresholding.

V. CONCLUSIONS

According to the criterion of efficiency, the proposed method is a simple one, having a minimal resource consumption and fast computation. The results achieved are numerically close to those obtained with more complex methods [6], [25], [26]. Therefore, we conclude that the method is effective and satisfactory. The quality of the results indirectly validates the use of the model of mixtures of Gauss and Uniform Noises (G-UN-MM) proposed in our previous papers.

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REFERENCES

[1] C.C. Kanga et al., Image segmentation with complicated background by using seeded region growing , International Journal of Electronics and Communications (AEÜ) (2012).

[2] A. Jellema et al., Landscape character assessment using region growing techniques in geographical information systems, Journal of Environmental Management 90 (2009), pp. 161–174.

[3] L. Liu, S. Sclaroff, Deformable model-guided region split and merge of image regions, Image and Vision Computing 22, (2004), pp. 343–354.

[4] W. Cai et al., Fast and robust fuzzy c-means clustering algorithms incorporaing local information for image segmentation, Pattern Recognition 40 (2007), pp. 825 – 838.

[5] Y.B. Chen, A robust fully automatic scheme for general image segmentation, Digital Signal Processing 21 (2011) pp. 87–99.

[6] P. Zhongliang et al., Threshold segmentation using cultural algorithms for image analysis, International Symposium on Photoelectronic Detection and Imaging 2007, Proc. of SPIE Vol. 6625, 662512, (2008).

[7] O.J. Tobias, R. Seara, Image Segmentation by Histogram Thresholding Using Fuzzy Sets, IEEE Transactions on Image Processing, Vol. 11, No. 12 (2002), pp. 1457-1465.

[8] B. Karasulu, S. Korukoglu, A simulated annealing-based optimal threshold determining method in edge-based segmentation of grayscale images, Applied Soft Computing 11 (2011), pp. 2246–2259.

[9] H. Zhang et al., Image segmentation evaluation: A survey of unsupervised methods, Computer Vision and Image Understanding 110 (2008), pp.260–280.

[10] K. Udupa et al., A framework for evaluating image segmentation algorithms, Computerized Medical Imaging and Graphics 30 (2006), pp.75–87.

[11] M. Sezgin, B. Sankur, Survey over image thresholding techniques and quantitative performance evaluation, Journal of Electronic Imaging 13(1), (January 2004), pp.146–165.

[12] D.E. Ilea, P.F.Whelan, Image segmentation based on the integration of colour – texture descriptors – A review, Pattern Recognition 44 (2011) pp.2479–2501.

[13] M. Sharma et al., Evaluation of Texture Methods for Image Analysis, Intelligent Information Systems Conference, The 7-th Australian and New Zealand (2001), pp. 117 - 121.

[14] J. Liu, Y.-H. Yang, Multi-resolution color image segmentation, IEEE Transactions on Pattern Analysis and Machine Intelligence 16 (7), (1994), pp. 689–700.

[15] HN. Teodorescu, M. Rusu,Yet Another Method for Image Segmentation based on Histograms and Heuristics, Computer Science Journal of Moldova, vol. 20, no.2(59), 2012, pp.163-177.

[16] The USC-SIPI Image Database, Available: http://sipi.usc.edu/database/database.php.

[17] Test Image, Available: http://www.ece.rice.edu/~wakin/images/lena512.bmp

[18] M. Rusu, H.N. Teodorescu, A Method for Image Segmentation based on Histograms - Preliminary Results. The 4-th Int. Conf. On Telecommunications, Electronics and Informatics, Chisinau 2012, pp. 351-354.

[19] Color-Based Segmentation Using K-Means Clustering, Available: http://www.mathworks.com/products/image/demos.html?file=/products/demos/shipping/images/ipexhistology.html#4.

[20] Image segmentation using Otsu thresholding, Available: http://www.mathworks.com/matlabcentral/fileexchange/26532-image-segmentation-using-otsu-thresholding/content/otsu.m.

[21] N. Otsu, A threshold selection method from gray-level histograms, IEEE Transactions on Systems, Man and Cybernetics 9 (1) (1979), pp.62–66.

[22] Blood cells image, Available: http://www.pudn.com/downloads58/sourcecode/math/detail206012.html (Last time accessed 21 June 2012).

[23] UTSA, CS 6723 Image Processing web page, http://vip.cs.utsa.edu/classes/cs6723f2001/lectures/lecture19.html.

[24] Standard image *peppers*, Available: http://introcs.cs.princeton.edu/java/31datatype/peppers.jpg

[25] S. M. Prasad et al., Unsupervised Image Thresholding using Fuzzy Measures, International Journal of Computer Applications (0975 – 8887), Vol.27, No.2 (2011) pp. 33-41.

[26] Y. T. Wu et al., A top-down region dividing approach for image segmentation, Pattern recognition, Vol. 41, 2008, pp. 1948-1960.