AUTOMATIC IMAGE SEGMENTATION USING MARKER CONTROLLED WATERSHED AND OVERLAP RATIO BASED REGION MERGING

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***Abstract*—In this paper, automatic image segmentation system is proposed to obtain accurate and meaningful segmented regions in an image with less over-segmentation. It includes three main approaches: preprocessing, segmentation and post processing steps. In the preprocessing step, the modified 7x7Laplacian of Gaussian (LoG) edge filter is implemented to compute the accurate approximation of gradient magnitudes. In segmentation step, marker controlled watershed method (MCWS) is applied on image gradient magnitude. Finally, the over-segmented regions are merged by using histogram similarity to merge the homogeneous regions. This system intends to produce the correct, useful and meaningful segmented results for medical analyzing tasks, objects detection and recognition in an image. It is tested on two different kinds of datasets: medical images and color natural image dataset. This system has also achieved accuracy 93.01% for MRI brain images, 76.72% for color natural images.**

Keywords—Marker-controlled watershed, Gradient, Region Merging, Over-segmentation

I. INTRODUCTION

Image segmentation is to divide an image into meaningful regions and extract those interested parts or objects from that image [3]. The accurate segmented results of image segmentation process play an important role for subsequent applications such as medical image segmentation, object detection, recognition and image visualization [1].

Most of conventional image segmentation methods require the considerable amount of interactive guidance to obtain the satisfactory segmentation results [4]. Moreover, images may have very complex structure due to shadow, low contrast areas, occlusion, cluttering and noise. These reasons make the difficulties for fully automatic image segmentation process [2]. It is also a very hard and challenging issue for producing accurate segmentation of different types of images. Therefore, in this paper, this present work is expected to handle the over segmentation problem of watershed methods and produce the accurate and useful segmentation results.

II. PROPOSED METHOD

The proposed system is performed by three main processes: preprocessing step, segmentation step and region merging. In preprocessing step, creating the modified 7x7LoG filter mask, filtering the grayscale image and computing the accurate gradient magnitude are performed to reduce the noise. In segmentation step, MCWS method is performed to remove the over-segmented regions. Then, region merging which is based on histogram similarity of two contiguous regions, calculation of overlap ratio and thresholding method are finally applied to merge the still over-segmented regions.

A. Gradient Computation and Noise Reduction

Firstly, the LoG function is used to create the modified 7x7 LoG filter kernel instead of 'Sobel filter' of existing watershed method.

$$LoG(x,y)=\frac{-K}{\pi\sigma^4}\left(1-\frac{x^2+y^2}{2\sigma^2}\right)e^{\frac{x^2+y^2}{2\sigma^2}} \quad (1)$$

The major concern of the proposed scheme is the choice of smoothing factor "σ" and high dependency on coefficient factor "K" for high enhancement. In this case, positive value 1.4 for smoothing factor σ and value 2670 for coefficient factor K are used to create two-dimensional filter. Scale factor 2670 is applied in creation of the modified LoG filter in order to reduce noise effect and to extract the correct gradient magnitude of the corresponding objects from the input image. This scheme forms gradient image and it is then processed to watershed segmentation.

B. Image Segmentation Step

To control over segmentation problem of watershed method, this approach is based on markers.

*1) Simplifying Input Image:*In this case, morphological opening filter with squared shaped structuring elements simplifies the input image to preserve the important contour information of objects. This structuring element achieves better filtering results for testing datasets.

2) Compute the Foreground and Background Marker: The proposed system uses morphological techniques called "openingbyreconstruction" and "closing-by-reconstruction" with a sequence of structuring element to "clean" up the image. These processeswill automatically create the foreground marker inside each object [5]. Thresholding operation on the clean-up image is taken to extract the background marker. The reconstructed image is used as thresholding level.

3) Modified Watershed Transform: To identify only regional minima wherever foreground and background marker pixels are not zero, the resulted image is imposed on gradient image. Extra pixels will be removed to prevent the over segmentation problem.

C. Region Merging Step

The region merging is considered on three measures: histogram similarity value $\delta(R_i,R_j)$, overlap ratio $O(R_i,R_j)$ and thresholding to merge the ambiguous boundaries of homogeneous regions.

For each possible pair of homogeneous regions, the image is divided into three color components on the whole image and extract the histogram of each part. Then it performs histogram normalization for each part. Histogram similarity $\delta(R_i R_j)$ is calculated on the sum of difference of total number of bins for each histogram. If histogram similarity $\delta(R_i R_j)$ is less than the threshold T_1, two regions are considered homogeneous region.

On the other hand, it alsohave to investigate on overlap ratio $O(R_i,R_j)$ whether two labeled regions R_i and R_j are contiguous.

$$O(R_i,R_j) = \frac{\sum(P(R_i) \cap P(R_j))}{\min((\sum P(R_i)),(\sum P(R_j)))} \quad (2)$$

$O(R_i,R_j)$ = overlap ratio

$P(R_i)$ = the number of pixels in region R_i,

$P(R_j)$ = the number of pixel in region R_j

If the histogram similarity $\delta(R_i R_j)$ is less than threshold T_1 and the ratio of overlapping $O(R_i,R_j)$ between two candidate regions is greater than T, the labeled region R_j is merged into labeled region R_i. In this case, according to the experiments, the fix threshold values are used; T is 0.001 and T_1 is 0.7. These threshold values achieve good performance of segmentation system and are suitable for both testing datasets.

III. Experimental Results and Performance Analysis

The system evaluates on two different types of images such as medical images, color natural images. Fig. 1 shows the comparison results of MCWS method and the proposed method. According to the experimental results, when the segmented results are analyzed with ground truth regions, conventional MCWS method has been observed 65% over segmentation problem on brain images and 80% over segmentation problem on color images. The proposed system has been found only 19% over segmentation problem on brain images and 41% over segmentation problem on color images. Therefore, the proposed system overcomes the over-segmentation problem than conventional MCWS method.

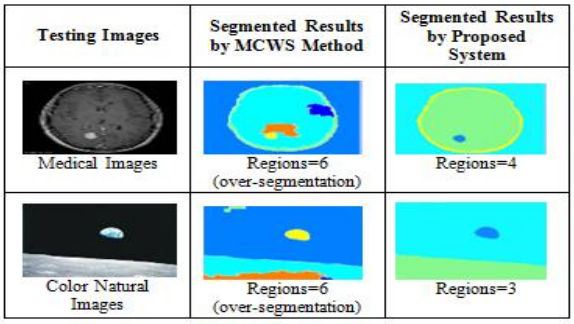

Fig. 1. Comparison of MCWS method's segmented results and the Proposed System's segmented result

The segmentation system is also evaluated on these performance matrixes: sensitivity, specificity and accuracy. Table I and Table II show the performance analysis on both testing datasets. According to experiments, the system had been achieved average sensitivity 85.70%, average specificity 93.69% and average accuracy 93.01% on overall 32 testing brain images. The system had been observed that average sensitivity 64.41%, average specificity 82.83% and average accuracy 76.72% on 181 testing color natural image dataset. It can be found the higher accuracy in medical images than color natural dataset.

TABLE I. Performance Analysis on Medical Images

Brain Images	*Sensitivity (True Positive Rate)*	*Specificity (True Negative Rate)*	*False Positive Rate*	*False Negative Rate*	*Accuracy*
B-0001	87.86	91.88	8.12	12.14	90.29
B-0002	77.92	96.62	3.38	22.08	95.78
B-0003	88.91	97.41	2.59	11.09	97.26
B-0004	98.18	93.45	6.55	1.82	95.85
B-0005	88.05	98.95	1.04	11.95	97.97
Average (%) on 32 brain images	85.70	93.69	6.31	14.30	93.01

TABLE II. Performance Analysis on Color Natural Images

Color Natural Images	*Sensitivity (True Positive Rate)*	*Specificity (True Negative Rate)*	*False Positive Rate*	*False Negative Rate*	*Accuracy*
N-0001	79.42	92.85	7.15	20.58	93.09
N-0002	76.34	94.04	5.96	23.66	88.65
N-0003	86.60	97.72	2.28	13.40	97.19
N-0004	75.99	93.61	6.39	24.01	87.98
N-0005	82.63	98.63	1.37	17.37	98.05
Average (%) on 181color images	64.41	82.83	17.17	35.59	76.72

IV. Conclusion

This proposed system can effectively solve over segmentation problem of conventional watershed method and also generate the satisfied segmented results for various types of images such as medical images and color natural images. Although the proposed system takes long time than existing MCWS method due to the region merging process, the proposed automatic image segmentation system gives better performance and accurate segmented results than existing MCWS method. Moreover, it has been observed that the accuracy for medical images is better than the accuracy for color natural images. Therefore, as a further extension, the proposed segmentation system can be improved to gain the higher accuracy of color natural image segmentation.

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