Integration of Marker Controlled Watershed and Region Merging Method for Image Segmentation

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Abstract

Automatic image segmentation is a very important task for image analysis, object detection and recognition tasks. In this research, automatic image segmentation system is proposed which includes three main approaches: preprocessing, segmentation and post processing approach. The preprocessing step estimates a better approximation of gradient magnitudes by the modified 7x7 Laplacian of Gaussian (LoG) edge filter. In segmentation step, marker controlled watershed method (MCWS) is applied to solve over-segmentation problem. Finally, the segmented regions are merged by using histogram similarity to obtain the accurate segmented regions in an image. This system is tested on two different kinds of datasets: medical image dataset and color natural image dataset. In this research, this system has also achieved accuracy 93.01% for brain image, 76.72% for color natural image. The running time of the proposed system takes five times than MCWS method for medical images due to region merging process for many complex regions.

Keywords*: Marker-controlled watershed, Gradient, Region Merging, Over segmentation.*

1. Introduction

Image segmentation separates the objects and components of the image. Segmentation algorithms are classified on the basis of the segmentation techniques like edge and contour based techniques, region based techniques, threshold selection based image segmentation techniques, etc. Subsequent applications such as image description, recognition, image visualization, image compression highly depend on the accurate results of segmentation step.

All these methods have their own limitations and advantages in terms of suitability, applicability, computer's memory space, transmission time of image data, computational cost and overall performance. A well-known region based algorithm is watershed segmentation method. This advantage of watershed algorithm gives the complete division of the image and close contour of objects. However, it causes over segmentation problem due to high-contrast of regional minima.

Last attempts to overcome this problem are tried by using many strategies. A combination of K-means, watershed segmentation method and Difference In Strength (DIS) map was used to perform image segmentation and edge detection tasks in [8]. Hybrid method of morphological structuring element map modification and marker controlled watershed segmentation was presented to reduce over segmentation problem of watershed method in [9]. Improvement of watershed segmentation based on maker was proposed for cell segmentation [1]. H.P.Ng et al. [3] proposed medical image segmentation using watershed and texture region merging. To compute gradient, sobel operator was used and then the automated thresholding performed as the post-segmentation merging which is based on histogram similarity. P.P. Acharjya et al. [5] proposed to find the edge of the image by using the modified mask of Laplacian of Gaussian edge operator and subsequent modulation of the edge by using watershed algorithm.

Other researchers also proposed different methods to avoid the problem of watershed. Although the researches mentioned above have their advantages, image segmentation is still active research area. For researchers, getting meaningful regions of a segmented image hard to try and it stands as a challenging issue. Therefore, in this paper, this research work is expected to handle the over segmentation problem and produce the meaningful result.

2. Watershed Image Segmentation

The watershed algorithm includes three basic segmentation approaches: threshold based, edge detection and region based segmentation [6] and hence it provides more stable results than these methods individually [7]. The segmentation idea of watershed came from the idea of partition of geographical landscape by the water level as shown in figure 1[2].

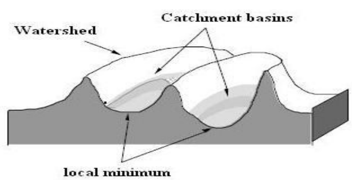


Figure 1. Geographical surface model for Watershed segmentation approach

Water is rising from the lowest minimum point. When the water level has been reached the highest peak, the rising water is stopped. At that point, dams are built to avoid the merging water from different catchment basins (CB). In practical, the whole image is segmented by the dams which are then called watersheds and the segmented regions are referred to as catchment basins. The gradient magnitude of the image can directly be processed prior to application of watershed transform for image segmentation. The advantages of watershed method are low computational complexity and high efficiency. The significant disadvantage of watershed segmentation is over segmentation problem.

2.1 Over Segmentation Problem

A significant problem of watershed method is over segmentation due to high contrast. It is a process that separates an image into super pixels that are groups of homogeneous pixel. Therefore, it can cause that image regions may be erroneously merged [4]. The over segmented image is very difficult to identify the size and area for each segment and segmented regions are not meaningful as shown in figure 2 (b).

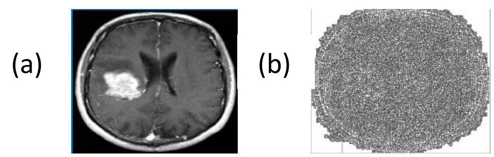


Figure 2. (a) Brain Image with tumor (b) Over segmented Image (number of regions=5753)

3. System Design and Implementation

The overview of the proposed system design is shown in figure (3). The overview of the system includes three main approaches: preprocessing (gradient computation), segmentation and region merging approach. In preprocessing step, the system is implemented to get better gradient magnitude and reduce the noise by the modified LoG edge filter. Then, the segmentation step with marker-controlled watershed method (MCWS) is performed to remove the over-segmented regions and the final region merging step is applied to obtain the meaningful segmented object in an image.

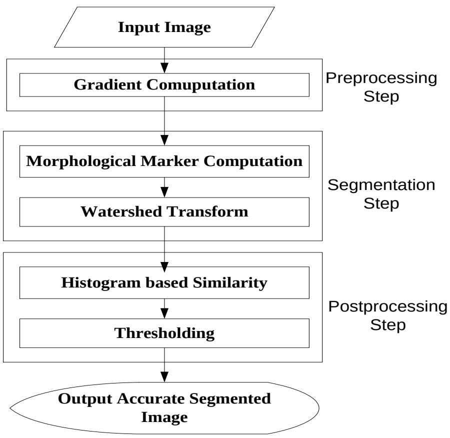


Figure 3. Overview of System Design

3.1 Gradient Computation

The gradient magnitude is often calculated to preprocess a gray-scale image before the segmentation. The modified 7x7 LoG edge mask is used to calculate the gradient values instead of Sobel mask of existing method. To generate the modified LoG filter, the LoG function is used as follow:

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

In the preprocessing step, 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 instead of coefficient value 1 of existing filter. Scale factor 2670 is applied in creation of the modified LoG filter in order to reduce noise effect on the grayscale image. Then calculate the gradient magnitude of the image by using the following equation.

$$G(x, y) = \sqrt{Gx^2 + Gy^2} \quad (2)$$

The modified LoG filter is implemented to extract the gradient magnitude of the corresponding objects from the input image. The system forms gradient image and it is then processed to watershed segmentation.

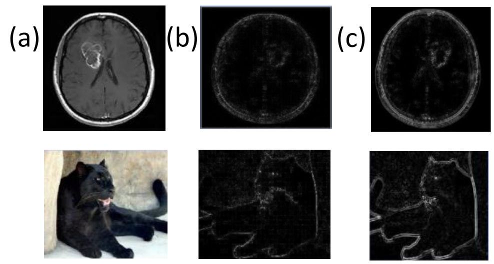


Figure 4. (a) Original MRI Brain Tumor Image (b) Gradient Image that is generated by LoG Filter with K=1 (c) Gradient Image that is generated by the modified LoG filter with K= 2670

3.2 Segmentation Step

This approach used to control over segmentation is based on markers. In this segmentation step, opening filter is firstly used to eliminate the noise and simplify the input images. Secondly, the foreground and background markers are extracted and then are imposed on the gradient image to mark the local maxima regions. Finally, the watershed algorithm is applied to the marked images to get the contour of objects in an image.

- **Simplifying Image**

Morphological opening filter simplifies the input image in order to remove local minima which are caused by irregular gray disturbance and noise, and preserves important contour information. For filtering process, the appropriate structural elements can be selected according to the size of impurities to suppress the noises of various intensities. If the reasonable scale of structuring element can be adjusted, the objects of image can be extracted and then the satisfied segmented results can be achieved. In this case, morphological opening filter with 9x9 squared shaped structuring elements is used. This structuring element achieves a better filtering result for all testing datasets.

- **Compute the Foreground Marker**

Marker extraction is to detect the presence of homogeneous regions after image simplification. A marker is connected component belonging to an image. Internal markers are inside each of the objects of interest (foreground object) while external markers are contained within the background. The proposed system uses morphological techniques called "opening-by-reconstruction" and "closing-by-reconstruction" with a sequence of structuring element to "clean" up the image. These operations will automatically create the foreground marker inside each object.

- **Compute Background Marker**

In the system, thresholding operation on the clean-up image is taken to extract the background marker. The reconstructed image is used as thresholding level. This level is a normalized intensity value that lies in the range [0, 1]. Therefore, the dark pixels belong to the background.

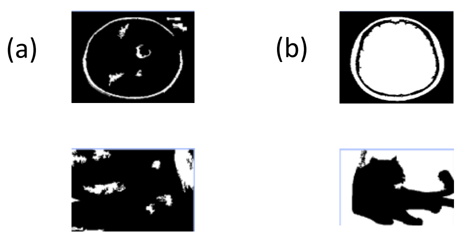


Figure 5. (a) Foreground Marker (b) Background Marker

- **Modified Watershed Transform**

Before applying watershed transform, the gradient image needs to have only regional maxima at one location of the foreground and background makers. Therefore, to modify the gradient image, these foreground and background markers from the previous steps are used.

Figure 6. Watershed Segmented Image

In this step, the image which has the foreground and background marker is imposed on the output gradient image from the previous gradient computation step to have only regional minima wherever foreground and background marker pixels are nonzero. Extra pixels will be removed to prevent the over segmentation problem. Then, the gradient image is directly processed through the watershed segmentation.

3.3 Region Merging Step

Although the segmentation step has been performed the satisfied segmented regions, there may be found some homogeneous regions with different labels in some cases. Therefore, it still needs to avoid this problem and still need to merge two homogeneous regions into one region. Therefore, the region merging algorithm is implemented to avoid further segmentation of homogenous regions.

The post process is considered on two measures: histogram similarity value and thresholding to merge the ambiguous boundaries of homogeneous regions.

For each possible pair of regions in watershed segmented image, the image is divided into three color components on the whole image and the histogram of each part was drawn. Then perform histogram normalization for each part. Histogram normalization achieves better performance in each segmented region. Then, 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 T1, two regions are considered homogeneous region.

On the other hand, investigate whether two labeled regions R_i and R_j are contiguous. Each labeled region is dilated with the ones 3x3 square structuring element respectively to be thicken the region boundary and to be easily detect the boundary pixels between R_i and R_j. Then the ratio of overlap O between these labeled region pair is calculated on the ratio of sum of contiguous pixels of two regions R_i and R_j and number of pixels of smaller region.

Table 1. Region Merging Algorithm

Input: Output:	Watershed Segmented Image Accurate Segmented Image
1.	Acquire the segmented labeled image L
2.	(i)Normalize the histogram for each color channel. (ii)Compute the histogram for each region in feature space 17 x17 x 17=4913 bins. (iii)Compute histogram similarity measure by : $\delta(R_i, R_j) = \sum_{u=1}^{4913} (\lvert Hist_{Ri}u - Hist_{Rj}u \rvert)$ where $\delta(R_i, R_j)$ denotes the histogram similarity measure, $Hist_{Ri}$ and $Hist_{Rj}$ are normalized histograms of Ri and Rj u represents the uth element of them.
3.	Check whether region Ri and region Rj are contiguous: $O(R_i, R_j) = \frac{\sum(P(R_i) \cap P(R_j))}{\min((\sum P(R_i)),(\sum P(R_j)))}$ where $O(R_i, R_j)$ denotes overlapping ratio; $P(R_i)$ is the number of pixels in region R_i. $P(R_j)$ is the number of pixel in region R_j.
4.	If $O(R_i, R_j) > T$ and $\delta(R_i, R_j) < T_1$), add R_j into R_i.
5.	Update the new label image until all possible region pairs have been processed in L

If the histogram similarity $\delta(R_i, R_j)$ is less than T_1 and the ratio of overlapping O between two candidate regions is greater than T, the labeled region R_j is added 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 thresholding values achieve good performance of segmentation system and are suitable for all testing datasets. Then, update the segmented labeled image until there is all possible region pairs have been processed.

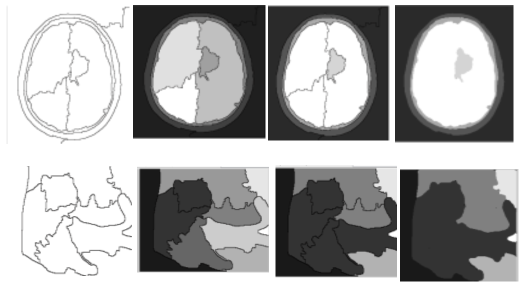


Figure 7. Steps of the Region Merging Process

In this research, the post processing step overcome the problem of further segmentation of homogeneous regions and achieve the accurate segmented image without affecting the overall shape of interested object in an image.

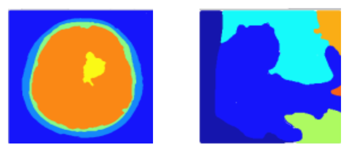


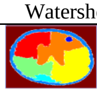
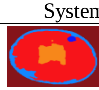
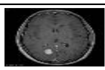
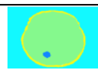
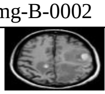
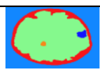
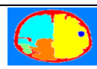
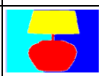
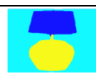
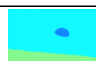
Figure 8. Final Segmented Images

4. Experimental Results and Analysis

Existing marker controlled watershed method overcomes the over segmentation problem. However, in some cases, this method cannot give the meaningful regions. According to Table 2, when the number of segmented regions of existing marker controlled watershed is compared with the number of ground truth regions, it has been observed 69% over segmentation problem, 16% under segmentation problem and only 15% the same result with ground truth on 32 brain image dataset. On 181 color natural image dataset, 80% over segmentation problem, 7% under segmentation problem and 12% same result with ground truth regions had been obtained.

The proposed system achieves nearly the same regions like the ground truth regions and also produces the meaningful segmented regions. When the proposed system is tested on 32 brain image dataset, this method has been observed only 22% over segmentation problem, 53% under segmentation problem and 25% the accurate result with ground truth. On color natural image dataset, 41% over segmentation problem, 17% under segmentation and 40% same result with ground truth regions had been achieved. Therefore, the proposed system gives better result than existing marker controlled watershed method.

Table 2. Analysis of Over segmentation

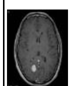
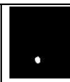
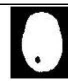
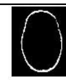
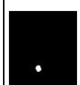
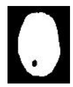
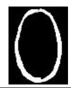
Number of Segmented Regions					
Image Type and Ground Truth regions		Marker Controlled Watershed		Proposed Segmentation System	
 Img-B-0001	6		8		5
 Img-B-0002	4		6		4
 Img-B-0003	5		7		5
 Img-N-0082	3		4		3
 Img-N-0165	3		6		3

4.1 Performance Analysis of the Proposed System

To evaluate the performance of the proposed segmentation system, sensitivity, specificity and accuracy were calculated over pairs of points.

In Table 3, the proposed system calculates the accuracy on each segmented region of brain image (Img-B-0002) with each ground truth region of Img-B-0002. In that image, the number of ground truth regions is 4. The proposed system segmented 4 regions on that image. The proposed system gives the close result with the ground truth regions. Therefore, the system must calculate the performance matrixes on four pairs of the segmented regions.

Table 3. Evaluation Accuracy for the Proposed System on each segmented region on Brain Image (Img-B-0002)

 Img -B- 000 2	Segmented Regions				
	Ground Truth				
	Accuracy (%)	99.97	99.02	91.62	92.48
The average accuracy of the whole image (on four region pairs)=95.78%					

The average sensitivity, specificity and accuracy which are tested on overall brain image dataset are presented in Table 4. According to experiments, the proposed segmentation system had been achieved average sensitivity 85.33%, average specificity 93.81% and average accuracy 93.15% on overall 32 testing brain image dataset. Similarity, the proposed 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. Therefore, the proposed system can give better performance on medical image dataset than color natural image due to natural images include various complex structure of objects.

Tables 5 and 6 show the running time comparison of conventional watershed, existing marker controlled watershed and the proposed system. According to experiments on two datasets, the proposed system takes more time than the other comparison methods because the proposed system performs the homogeneous regions merging process to obtain the accurate and meaningful segmented regions.

Table 4. Performance Analysis on Brain Image Dataset

Brain Images	Sensitivity (True Positive Rate)	Specificity (True Negative Rate)	Accuracy
Img-B-0001	75.93	96.02	94.59
Img-B-0002	77.92	96.62	95.78
Img-B-0003	88.91	97.41	97.26
Average Percentage (%)	85.33	93.81	93.15

Tabel 5. Running Time Comparison on Brain Images

Running Time in Seconds			
Brain Images	Conventional Watershed	Marker Controlled Watershed	Proposed System
Img-B-0001	0.17	0.41	1.58
Img-B-0002	0.13	0.35	0.73
Img-B-0003	0.12	0.35	0.78
Average Time	0.19	0.49	1.81

Table 6. Running Time Comparison on Natural Images

Running Time in Seconds			
Natural Images	Conventional Watershed	Marker Controlled Watershed	Proposed System
Img-N-0001	0.15	0.31	1.65
Img-N-0002	0.14	0.28	2.20
Img-N-0003	0.15	0.26	2.76
Average Time	0.19	0.40	3.32

5. Conclusion

This proposed system can effectively solve over segmentation problem of traditional 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 marker controlled watershed method due to the region merging process, the proposed automatic segmentation system gives better performance and accurate segmented results than existing marker controlled watershed method. Moreover, it has been observed that the accuracy for medical images is better than the accuracy for color natural images. Therefore, the proposed system is useful for medical analysis and object detection.

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