Automatic Natural Image Segmentation By Using Marker Controlled Watershed Method and Region Merging Method

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Abstract

Fully automatic image segmentation is a difficult task for natural images because of many variations as contrast and complex background. Conventional segmentation methods require a considerable amount of interactive guidance by the user to attain satisfactory results. Moreover, the most subsequent tasks as object detection and image analyzing application highly depend on the accurate and useful segmented result. Therefore, in this paper, an automatic image segmentation method for natural images is proposed. The proposed system includes three approaches: gradient computation with the modified LoG edge filter, marker-controlled watershed segmentation (MCWS) with automatically marker selection and region merging approach that is based on edge strength and homogeneous intensity. The system can not only efficiently reduce the significant over segmentation problem of watershed algorithm and but also produce the correct and meaningful segmented images It purposes better performance of segmented images for image annotation, objects detection, image analyzing task and computer vision.

***Keyword**: Region merging, Marker-controlled watershed, Gradient, Mean Intensity*

1. Introduction

Image Segmentation separates the objects and components of the image [1],[4],[14]. 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. 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.

Watershed segmentation is region based segmentation method. The significant problem of watershed is over-segmentation problems which were addressed in numerous literatures [2], [13], [10]. The complete division of the image through watershed algorithm relies on the high contrast. Over segmentation problem may be found due to the rough estimation of gradient and high contrast. Conventionally, watershed transform is mostly designed for the purpose of grayscale image segmentation.

Although various spatial and frequency domain filtering techniques exist to approximate the gradient magnitude, in this paper, Laplacian of Gaussian (LoG) edge filter is used in gradient calculation. LoG edge detector is combined with the watershed segmentation to yield good approximation of gradient magnitude.

The present study introduces the concept of marker as the pretreatment before separating the image to overcome the over segmented problem. Then, region merging technique which is based on homogeneity properties of adjacent regions is applied to produce the final meaningful and useful segmented regions without over segmentation. By comparing with traditional watershed, the proposed system has been already observed that the watershed segments are very prominent and the watershed boundaries are also very sharp and therefore, this can easily reduce over-segmented regions. The proposed method can give more accurate segmentation results than existing watershed method and can more efficiently reduce the over-segmentation of the watershed algorithm.

The structure of this work is the following: Section 2 introduces the previous works concerned with image segmentation. Section 3 presents the watershed segmentation. Section 4 presents the brief of region merging. Section 5 describes the detailed steps of the proposed system. The results are discussed in section 6 and we finish this paper with some concluding remarks with section 7.

2. Related Works

A good number of works has already been carried out on watershed segmentation and applied to solve the problems related to digital image segmentation. These are available in the published or online literature.

Pinaki Pratim Acharjya, Santanu Santra, Dibyendu Ghoshal presented an improved scheme on morphological image segmentation using the gradients. They introduced the concept of edge detection with gradient and used the system to produce an effective watershed technique for natural images [12].

Pinaki Pratim Acharjya, Dibyendu Ghoshal discussed a gradient based morphological watershed segmentation approach that is suitable for human visual system. They had shown that watershed segmented image obtained by modified LoG mask appears to be much more clear with sharp and prominent watershed ridges and the number of segmented have been found to much less than conventional filter[11].

An improved image segmentation approach based on level set and mathematical morphology was presented [3]. The gradient magnitude of the smoothed image is input to the watershed transformation, the result of watershed is used for rough approximation of the desired contour in the image, and guide for the initial location of the seed points used in the following level set method.

In order to avoid over segmentation, generally marker controlled watershed technique [8] is followed but the whole process has been found to be a comparatively lengthy process in terms of computation. Therefore, many researchers had to try an efficient technique which may yield larger segmented regions and it can be expected that it would solve for the suppression of over segmentation and it will be also easier for handling by the machine.

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.

3. Watershed Image Segmentation

The watershed transform can be classified as a region-based segmentation approach. The intuitive idea of this method comes from geographical surface: it is that of a landscape or topographic relief which is flooded by water. Bechuer[6] categorized watershed into two approaches. In rainfall approach, watersheds are the divide lines of the domains over the region [12]. An alternative flooding approach is to imagine the landscape being immersed in a lake, with holes pierced in local minima. Basins (also called catchment basins) will fill up with water starting at these local minima, and, dams are built at points where water coming from different basins would meet. When the water level has reached the highest peak in the landscape, the process is stopped. As a result, the landscape is partitioned into regions or basins separated by dams (watershed lines or simply watersheds).

In practice, image regions are related catchment basins and also watershed ridge lines correspond to edges of images. 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.

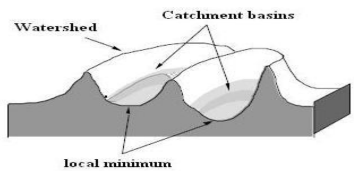


Figure 1. Geographical surface model for Watershed Segmentation approach

3.1 Over segmentation Problem

Figure 2. (a) Color Natural Image (b) Oversegmented Image

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. 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).

The low-contrast [9] edges produce an under segmentation. This process generates small magnitude gradients, and therefore, this causes the distinct regions to be erroneously merged. The proposed system is mainly addressed to solve over segmentation problem of watershed algorithm.

3.2 Marker Controlled Watershed Segmentation (MCWS)

To solve the over segmentation problem of watershed, MCWS performs the basic procedure:

1. Compute a segmentation function. This is an image whose dark regions are the objects that are tried to segment.
2. Compute foreground markers. These are connected blobs of pixels within each of the objects.
3. Compute background markers. These are pixels that are not part of any object.
4. Modify the segmentation function so that it only has minima at the foreground and background marker locations.
5. Compute the watershed transform of the modified segmentation [5].

3.3 Marker Extraction

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.

These markers are used to modify the gradient to overcome over segmentation problem.

4. Region Merging Approach

Regions are sets of pixels with homogenous properties and they are iteratively grown by combining smaller regions or pixels.

Region merging techniques usually work with a statistical test to decide the merging of regions. A merging predicate uses this test, and builds the segmentation on the basis of (essentially) local decisions. A good region merging algorithm has to find a good balance between preserving this unit and the risk of over merging for the remaining regions [7].

In the proposed system, region merging performs as a post-processing technique that merges adjacent regions according to two predicates:

(a) A dissimilarity measure which is used to determine the candidate region pair for merging

(b)A consistency property which checks if the regions have homogenous properties.

5. Overview of the Proposed System

The overview of proposed system includes three main approaches: preprocessing approach, segmentation approach 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. The overview of the proposed system design is shown in figure (3).

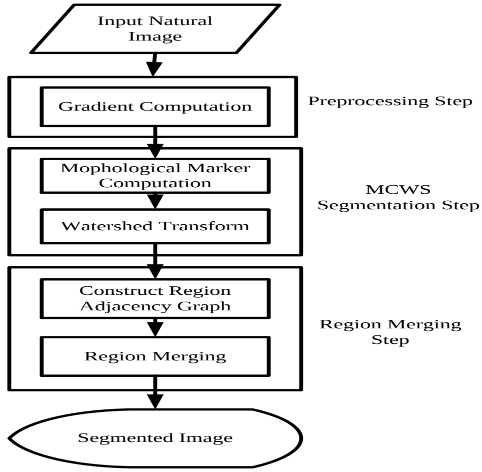


Figure 3. Overview of System Design

5.1 The Proposed System Design

This section describes how to implement the proposed image segmentation algorithm.

Table 1. Automatic Image Segmentation Algorithm

Input:	Natural Image
Output:	Meaningful Segmented Image
1.	Gradient Computation of the image
2.	Automatically extraction the markers by using opening-closing by reconstruction
3.	Finding the regional minima of the reconstructed image.
4.	Segmentation the image by watershed transformation
5.	Construction the region adjacency graph and acquire the adjacent region pairs
6.	Calculation of minimum edge weight for each chosen region pair in RAG
7.	Calculation of Mean intensity for each region pair
8.	Merging two regions if the regions have minimum edge weight and similar mean intensity.
9.	Go to step 6 if the regions are not consistent the condition of step 8 and check again for next region pair.

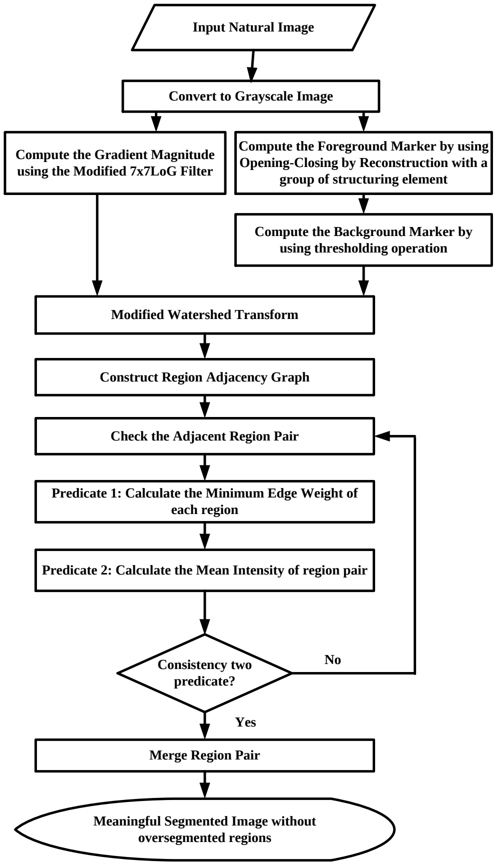


Figure 4. Block Diagram of the Proposed System

The proposed algorithm and the detail block diagram are shown in table 1 and figure 4, respectively. The detail steps of the proposed system are as follow:

Preprocessing step: The image is firstly converted to gray level image for processing the subsequent algorithms. Then, we perform to compute the better gradient magnitude by the modified 7x7LoG edge filter.

- Compute the Gradient Magnitude

In the proposed system, the modified 7x7 LoG edge mask is used to calculate the gradient values instead of sobel mask of conventional watershed method. To generate the modified edge mask, LoG function is used as follow:

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

It is centered on zero and approximated with Gaussian delta 1.4 and the coefficient factor K. Then calculate the gradient magnitude of the image by using the following equation.

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

The gradient image with better gradient values is then processed to watershed segmentation.

Segmentation Step: This approach used to control over segmentation is based on markers.

- Compute the Foreground Marker

In the proposed system, "Opening-by-reconstruction" and "closing-by-reconstruction" with a group of structuring element are used to extract the foreground marker.

This system used a sequence of structuring elements s_i= {s_i |1,2,…..,n} have the same shape and size of s_i which increases with i monotonically to exactly detect the shape of objects. Opening and closing operation is performed with 3x3 mask which is the basic structure of s_i and then it increased with (2i+1) * (2i+1) pixels to choose the multi-scale morphological structuring elements. Then, construct the reconstructed image. These operations will automatically create foreground marker inside each object.

- Compute the Background marker

This section takes thresholding operation on the reconstructed image that is obtained after the opening by reconstruction operation. The reconstructed image is identified as the threshold level. In this case, the dark pixels belong to the background.

- Modified Watershed Transform

After the new gradient image is created with both foreground and background markers, we find the location of regional minima so that its only regional minima occur at foreground and background marker pixels. Extra pixels will be removed to prevent the over segmentation problem. Then, the gradient image is directly processed through the watershed segmentation. However, there still remain to merge neighboring regions that yield a meaningful segmentation.

Region Merging Step: To merge the regions, the two predicates that are based on measuring the dissimilarity between the two regions are proposed.

- Construct Region Adjacency Graph

After acquiring the segmented image by the proposed MCWS algorithm, we construct RAG graph to represent the object edge and regions in an image. Let G = (V, E) be an undirected graph, where $v_i \in V$ is a set of nodes corresponding to the objects in the image. E is a set of connecting edges between the neighboring nodes. Then, check the adjacent region pair. In RAG, there exit an edge between two nodes if these nodes are adjacent. After that, extract the adjacent region pair from RAG.

- Predicate1: Calculate the minimum edge weight of each region

In a RAG graph, each edge $(v_i,v_j)\in E$ has a corresponding weight $w((v_i,v_j))$. To obtain dissimilarity measure of neighbor region pairs, the minimum weight edge between two neighboring regions (R_1, R_2) can be calculated as follow:

$$W(R1,R2) = \min_{vi \in R1, vj \in R2, (vi,vj) \in E}(w(vi,vj)) \quad (2)$$

- Predicate 2: Calculate the mean Intensity of each region

Two regions, R1 and R2 are merged if R1 and R2 have minimum difference in mean intensity. The arithmetic Mean Intensity m(R):

$$m(R) = \frac{1}{n}\sum_{(Pi,Pj)\epsilon R} I(Pi,Pj) \quad (3)$$

If the minimum pair R1 and R2 does not satisfy the two predicates, this minimum pair is ignored for region merging. Then, evaluate the next region pair by using the previous processes.

- Merge region pair according to two predicates

If the two predicates are consistent, these region pair will be merged to get the meaningful segmented regions. In this way, the region merging is repeatedly performed until meaningful regions are obtained.

6. Results and Discussion

The focus on this experiment is both for producing better image segmentation results by using the decision of region merging and solving over segmentation problem by using marker controlled watershed segmentation. The experiments are tested on colorful natural images. Figure.5 (a) and figure.6 (a) display the original colorful images.

The image is converted to gray level images for processing the subsequent algorithms. Then, the gray level image has been processed to get the corresponding gradient images by using modified 7x7 LoG mask as shown in figure 5(b) and figure 6(b). If the gradient images can be directly applied to watershed segmentation, there may be found extremely over segmented regions as shown in figure 5(c) and 6(c).

Therefore, in order to reduce the over segmented regions, image regions must be processed with proposed MCWS as shown in figure 5(d) and 6(d). Figure 5(e) and 6(e) can be clearly seen the better segmented regions than regions that are obtained by the existing watershed method.

Figure 5(f) and 6(f) respectively present that the regions are merged according to the proposed algorithm to make regions meaningful. Finally, the proposed system can generate the meaningful regions of the image that are useful for the purposes such as image annotation, object detection and so on.

Table 2 shows the performance evaluation on two testing images how many over segmented regions can be reduced by the proposed system. By comparing with conventional watershed method, the proposed system can produce better segmented image without over segmentation.

(a) (b) (c)

Figure 5. (a) Original Image 5(b) Gradient Image by the modified 7x7LoG filter 5(c) Over segmented Image by conventional watershed

(d) (e) (f)

5(d) Marker Image 5(e) Segmented Image by MCWS 5(f) Meaningful Segmented Image by the Proposed Method

(a) (b) (c)

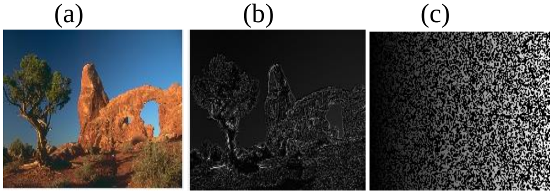
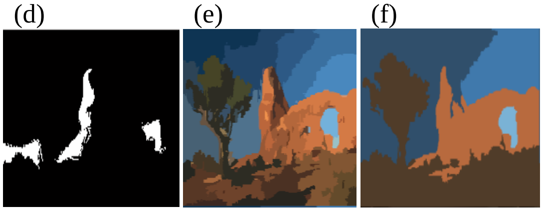


Figure 6. (a) Original Image 6(b) Gradient Image by the modified 7x7LoG filter 6(c) Over segmented Image by conventional watershed

(d) (e) (f)



6(d) Marker Image 6(e) Segmented Image by MCWS 6(f) Meaningful Segmented Image by the Proposed Method

Table 2. Performance analysis for over segmentation problem

Segmentation Methods	Tested Images	Number of regions after segmentation
Conventional Watershed method	Figure 5(c)	4789 (over Segmentation)
	Figure 6(c)	16669 (over segmentation)
The Proposed Method	Figure 5(f)	7
	Figure 6(f)	6

Table 2. Analysis for Correct Segmented Image by PSNR and MSE

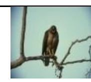
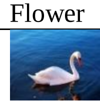
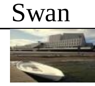
Testing Natural Images	The Proposed Method		Conventional Watershed Method	
	PSNR	MSE	PSNR	MSE
 Flower	35.98	11.42	36.12	11.54
 Bird	8.3	7.74	8.36	7.79
 Flower	12.86	11.75	13.14	12.05
 Swan	9.75	9.75	9.86	9.86
 Ship	11.23	10.3	11.56	10.59

Table 3 represents mean square error (MSE) and Peak Signal-to-Noise Ratio (PSNR) values for measuring the quality of final segmented images. MSE evaluates segmentation errors between the original image and segmented image. A higher PSNR indicates the lower MSE values. We have observed that the proposed method results less error values of final segmented image than existing watershed method. In this paper, experimental results are obtained by using MATLAB R2010a.

6. Conclusion

Segmentation accuracy determines the success or failure of computerized analysis procedure. Correct segmented results are very useful for the analysis, predication and diagnoses.

Automatic image segmentation is still a demanding issue in image analyzing task. Therefore, we have proposed a very effective automatic image segmentation method. The proposed method with modified 7x7LoG filter can make better localization when the edges are not very sharp and better output in term of image quality, clarity and sharpened edges of objects. The proposed Marker controlled watershed method can solve over segmentation problem well and the proposed region merging approach can generate the meaningful and acceptable results for subsequent analyzing tasks. The presented method has been found to yield better performance in term of image quality, clarity, sharpness and meaningful regions.

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