Automatic Image Segmentation using Gradient based Morphological Watershed Transformation

Khin Lay Mon[1]

Abstract— Image segmentation has been an essential step in digital image processing for most subsequent image analysis and image understanding activities. Many conventional segmentation methods require a considerable amount of interactive guidance in order to attain satisfactory results. Therefore, in this paper, fully automatic image segmentation which is usually a difficult segmentation task for natural images is proposed. This system is based on mathematical morphology to control over segmentation problem of watershed segmentation. Therefore, in this system, the modified 9x9LoG filter is applied to produce a better approximation of gradient magnitudes and then the improved watershed algorithm based on the marker is performed. This system requires simpler parameters and lower computation than other traditional watershed methods. The system can efficiently reduce over segmentation of watershed algorithm and get the meaningful segmented image that are useful for image annotation, objects detection in an image and image retrieval systems.

Keywords—Laplacian of Gaussian filter, Morphological Gradient, Watershed algorithm, Marker-controlled watershed Transformation

I. Introduction

IMAGE segmentation separates the objects and components of the image [4-6]. 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.

Over-segmentation is a significant problem for most watershed algorithms, which were addressed in numerous literatures [12-13]. Conventionally, watershed transform is mostly designed for the purpose of image segmentation. The division of the image through watershed algorithm relies mostly on an estimation of the gradients. The low-contrast [14] edges produce an under segmentation and generate small magnitude gradients, and therefore, this causes the distinct regions to be erroneously merged. Although various spatial and frequency domain filtering techniques exist, in this paper, Laplacian of Gaussian (LoG) edge detector are used. LoG edge detector is combined with the watershed segmentation to yield good approximation of gradient magnitude.

The present study introduces the improved gradient based watershed segmentation method. This system is applied morphological reconstruction before performing segmentation on images and based on the concept of marker to overcome the over segmented problem. Modified 9x9LoG edge detection operator is also used with the watershed algorithm to generate the final meaningful segmentation results with less over segmentation. By comparing with other traditional watershed, the improved method has been already found that the watershed segments are very prominent and the watershed boundaries are also very sharp and this lower scale of over segmentation will enable the computers to process the segmented images more easily and with lower cost. The method can give more accurate segmentation results than other tradition methods. This system requires fewer computations and simpler parameters and can more efficiently reduce the over-segmentation of the watershed algorithm.

In the present study, Laplacian of Guassian (LoG) edge detection operator is used with the watershed algorithm to generate the final segmentation results with less over segmentation. Although the 5x5 LOG filtering mask proposed by Marr-Hildreth [11] is a default mask, the mask can be extended dimensionally on the basis of the need of the image processing situation. A modified scheme of LoG operator with 9x9 mask to find an edge and contour of a digital image is proposed and produces greater accuracy and lesser over segmentation in edge detection with subsequent modulation of the edge by using watershed algorithm. It has been found from the segmented image that in this case the over segmentation is appreciably less than those obtained by using other edge detecting techniques. It has been already found that the watershed segments are very prominent and the watershed boundaries are also very sharp and this lower scale of over segmentation will enable the computers to process the segmented images more easily and with lower cost.

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 a brief description of gradient magnitude based watershed segmentation. Section 5 describes the proposed scheme of modified Laplacian of Gaussian moderator with9x9 mask and morphological watershed method. The results are discussed in section 6 and we finish this paper with some concluding remarks with section 7.

II. Related Works

A good number of works has already been carried out on

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watershed segmentation and applied to solve the problem related to digital image segmentation. These are available in the published or online literature. 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 7x7 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 conventional5x5LoG filter[1].

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 [8].

An improved image segmentation approach based on level set and mathematical morphology was presented [15]. Jie Chen et al [9] discussed an improved watershed algorithm was created with a plug-in function in flooding process and the way of image reconstruction. Hamarneh and Li [10] have proposed a method of watershed segmentation using prior shape and appearance knowledge to improve the segmentation results. In order to avoid over segmentation, generally marker controlled watershed technique [7] 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. They expected that it would solve for the suppression of over segmentation and it will be also easier for handling by the machine. Although the researchers mentioned above have their advantages, getting meaningful segmented image with less over-segmented regions is still active research area. Therefore, in this paper, this research work is expected to overcome the over segmentation problem and produce the meaningful result.

III. WATERSHED SEGMENTATION

The watershed transform can be classified as a region-based segmentation approach. The intuitive idea underlying this method comes from geography: it is that of a landscape or topographic relief which is flooded by water. In rainfall approach, watersheds are the divide lines of the domains over the region [1]. An alternative 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, at points where water coming from different basins would meet, dams are built. 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, called 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.

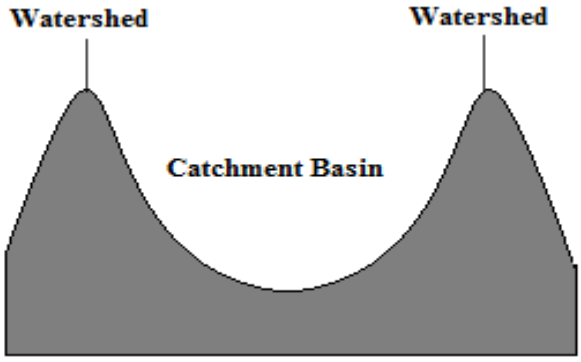


Figure.1 Watershed segmentation-local minima of gray level yield catchment basins, local maxima define the watershed lines

IV. GRADIENT MAGNITUDE BASED WATERSHED METHOD

The gradient image is computed to preprocess a grayscale image before applying watershed approach. The gradient magnitude image indicates high pixel values along object edges, and low pixel values at low variations. The gradient magnitude of the discrete grayscale image is computed by using linear filtering method i.e. by convolving the discrete image matrix with the filter mask. The weak point of gradient magnitude based watershed method generally leads to over-segmentation of an image due to noise and other local irregularities of the gradient. Solution is to limit the number of allowable regions by incorporating an additional knowledge into the segmentation procedure. Here, modified 9x9 Laplacian of Gaussian (LoG) mask is used to compute better approximation of gradient.

0	1	2	4	4	4	2	1	0
1	3	7	10	11	10	7	3	1
2	7	11	7	1	7	11	7	2
4	10	7	-24	-48	-24	7	10	4
4	11	1	-48	-83	-48	1	11	4
4	10	7	-24	-48	-24	7	10	4
2	7	11	7	1	7	11	7	2
1	3	7	10	11	10	7	3	1
0	1	2	4	4	4	2	1	0

Figure.2 Modified 9x9 Laplacian of Gaussian filter mask with Gaussian delta 1.4

V. PROPOSED SCHEME

In the proposed scheme, edge detection filter plays as a very important role. Modified 9x9Laplacian of Gaussian (LoG) edge detector, a convolution filter, is used to highlight edges of different objects in natural images. It takes a single gray level image as an input image and produces another binary image as output. It has been found and studied that LoG mask can be extended in any arbitrary size for more accurate detection of objects. Therefore, we have tried to extend the conventional LoG mask to detect more correct edge as a new approach. After large number of trials using masks of larger

dimensions, the size of the optimal mask was obtained and found to have 9x9 in dimensions. We have found that there is no loss of generality by using this mask even if the weights of individual pixel in the masks are changed slightly. However, we have subsequently to try for obtaining the meaningful results that are useful for image annotation and image retrieval systems. Therefore, the proposed system is used marker controlled watershed segmentation to get the meaningful result with less over-segmented regions.

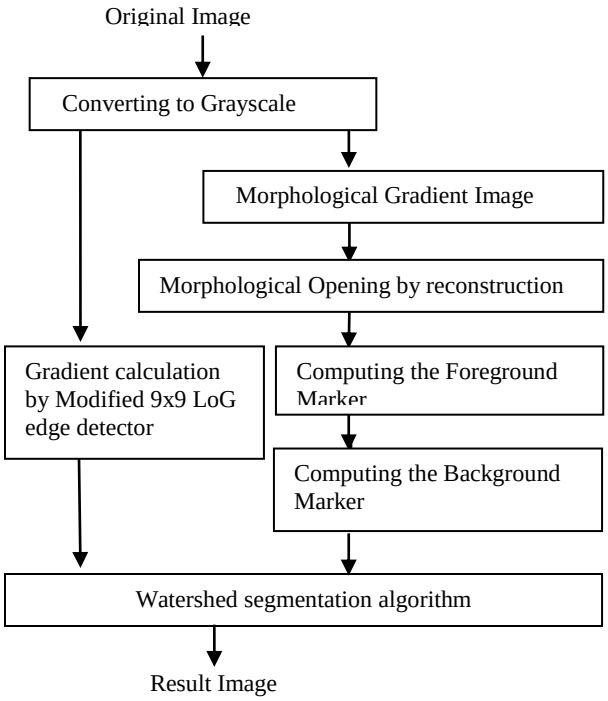


Figure.3 Block diagram of the proposed system

The approach is based on the concept of markers. A marker is a connected component belonging to an image. We have to define internal markers, associated with objects of interest, and external markers, associated with the background. The block diagram of the proposed system as shown in figure (3) is represented an automatically procedure for marker selection which takes the following steps.

Step1: Compute morphological gradient of an image (G):

$$G = (I \oplus SE) - (I \ominus SE) \quad (1)$$

where I is the original image. In this case, the morphological gradient G obtained using symmetrical structuring elements SE tend to depend less on edge directionality. The gradient magnitude highlights the highest gray-level transitions in the input image.

Step2: Perform the idea of morphological opening by reconstruction to create flat maxima inside each object for using foreground marker.

Step3: Enumerate foreground markers that are associated with objects of interest and background markers that are associated with the background.

Step4: Utilize watershed segmentation algorithm.

The segmented output that are obtained by using the proposed system is more pleasing without over-segmentation and the algorithm is also less time complex than other conventional algorithms.

VI. Result and Discussion

The focus on this experiment is both for getting better image segmentation result and solving over segmentation problem by using marker controlled watershed segmentation and modified LoG edge detector. The experiments are carried out color images from real life. Figure 4(a) and 5(a) respectively display the original colorful images that are obtained from real life.

The image is converted to gray level image for processing the subsequent algorithms. In watershed segmentation, a gray level image can be interpreted as the topographic image of landscape. Then, the gray level image has been processed to get the corresponding gradient image by using modified 9x9 LoG mask. The gradient image can be directly applied to watershed segmentation. Figure 4(b) and 5(b) are represented the gradient images that have been observed with the proposed LoG filter. The conventional 5x5LoG edge detector have produced pale edges (i.e, the edges in image are not very sharp). The proposed 9x9LoG filter can give more enhance gradient images than conventional 5x5LoG filter. In this stage, although we can easily detect sharp edge of objects with proposed 9x9LoG filter, many over-segmented regions that are not suitable in subsequent tasks can be still found. Therefore, to reduce over segmented region, a solution can be achieved by using Marker controlled watershed segmentation.

The foreground and background marker are used to segment the image correctly. Figure4 (c) and 5(c) respectively are represented as the superimposed image with the markers and boundaries of objects. Finally, we can easily see the meaningful segmented image that are useful for subsequent analysis tasks as shown in figure 4(d) and 5(d) respectively.

In this experiment, it has been observed that the edges and boundaries of the images are also seen to be more prominent and clear with better contrast and less over segmented regions. The segmented images through the watershed segmentation by using conventional 5x5LoG mask have been found extremely over segmented regions. Although the proposed method can reduce the less over-segmented regions than conventional 5x5LoG filter and can perform to segment various shape of objects, it take too long for larger size of natural images. However, the proposed filter can be optimized and performed every natural image that has 1024x1024 and less than this size to get the meaningful segmented image without over-segmented regions.

Figure4(a) Original Image (b) Grayscale Image

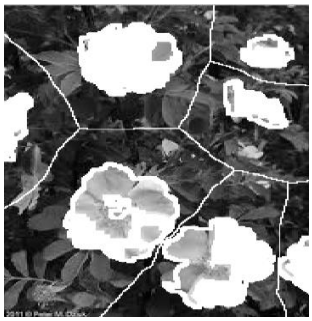


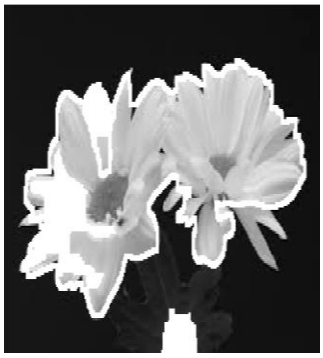
Figure4(c) Superimposed image with markers and object boundaries on original image

(d) Final meaningful segmented image by using proposed method

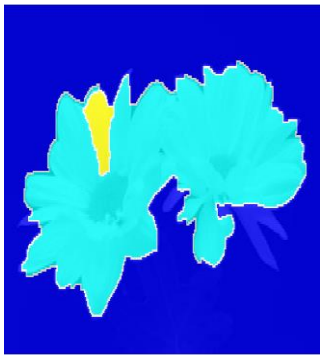
Figure5(a) Original Image

(b) Grayscale Image

The entropies of the final segmented images by using marker controlled watershed segmentation through 5x5LoG filter and the marker controlled watershed with the proposed 9x9 LoG filter have been calculated and the values have been shown in the table 1. Experimental results presented in this paper are obtained by using MATLAB R2010a.



(c) Superimposed image with markers and object boundaries on original image



(d) Final meaningful segmented image by using proposed method

Figure	Figure (4)	Figure (5)
Entropy value of Segmented Image that are obtained by Marke Controlled Watershed Segmenta with 5x5LoG	1.7364	0.9977
Entropy value of Segmented Image Obtained by Marker Controlled Watershed Segmenta with 9x9LoG	1.7227	0.9964

VII. Conclusion

The proposed technique focuses on the solution of over segmentation problem of natural images by applying a specific pre-processing stage. A preprocessing method with modified LoG edge detector performs to reduce the noise of image and adjust the image intensity. Therefore, it can produce simultaneously de-noising image and edge enhancement. In our approach, the satisfied gradient image is obtained by applying watershed transformation with optimized 9x9LoG filter. An idea of marker controlled watershed has been subsequently processed to get the useful results. Our experimental results indicate that the over segmentation problem of watershed can be significantly reduced and give better output in term of image quality, clarity and sharpness. Therefore, this system can be very helpful for image annotation to detect an accurate image clearer. The proposed system can be extended to choose an auto-adaptive capability of the structural elements for a particular application as the future work.

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