Automatic Image Segmentation Using Edge and Marker-Controlled Watershed Transformation

Khin Lay Mon

***Abstract*—**Image segmentation has been a difficult task in computer vision. The role of image segmentation is to decompose an image into parts that are meaningful with respect to the particular applications. Subsequent methods for image description, recognition, image visualization, image compression, highly depend on the segmentation results obtained from previous stage. Therefore, we propose an automatic image segmentation method by combining an edge detection technique with modified mask as a preprocessing method and Marker Controlled Watershed Transformation (MCWT) for final image segmentation. In this paper, watershed algorithm with modified Laplacian of Gaussian (LoG) edge detector is used to detect the gradient image of input image and produce the image which is less sensitive to noise. In order to get final image with less over segmentation, it is helped by MCWT. Therefore, our proposed method has also been observed a satisfactory segmentation image with better edges and with less over segmentation.

***Keywords*—**Laplacian of Gaussian filter, Zero Crossing, 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. The main aim of segmentation is to find certain interested objects which may be depicted in the image. But it is encountered with noise. That means if an image contains noisy signals, this result makes an unwanted segmentation and cannot detect the detailed image. Noise is the random variation of brightness or color information which is either due to technology limitation or environmental factor. It produces unpredictable results. Therefore, before performing segmentation on images, it is necessary to remove noise from it.

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, causing distinct regions to be erroneously merged. Although various spatial and frequency domain filtering techniques exist, in this paper, Laplacian of Gaussian (LoG) edge detector is used. LoG edge detector is combined with the watershed segmentation to yield good results.

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 conventional Laplacian of Gaussian edge detection operator for gradient images. Section 4 presents a brief description of watershed segmentation. Section 5 describes the proposed scheme of modified Laplacian of Gaussian moderator with9x9 mask. 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 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

Khin Lay Mon is with the University of Computer Studies, Mandalay, Myanmar. (Corresponding author's e-mail: khinlaymon.tk@gmail.com).

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].

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[1].

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 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. An improved image segmentation approach based on level set and mathematical morphology was presented [15]. 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.

Although the researchers 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 overcome the over segmentation problem and produce the meaningful result.

III. Laplacian Of Gaussian

This detector finds edges by looking for zero crossings after filtering f(x, y) with a Laplacian of Gaussian filter. In this method, the Gaussian filtering is combined with Laplacian to break down the image where the intensity varies to detect the edges effectively.

It finds the correct place of edges and testing wider area around the pixel. It have been observed and studied that the standard mask of Laplacian of Gaussian edge detector of 5x5mask can be modified and the scheme can be improved for generating masks of arbitrary size for gradient images for more accurate detections of object edges in a digital image. A 5x5 mask LOG filter has been shown in below.

0	0	1	0	0
0	1	-2	-1	0
-1	-2	16	-2	-1
0	-1	-2	-1	0
0	0	-1	0	0

Fig. 1 A conventional 5x5 mask LoG filter

IV. Watershed Segmentation

The watershed transform is a broadly used technique for image 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, watersheds being the divide lines of the domains of attraction of rain falling 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.

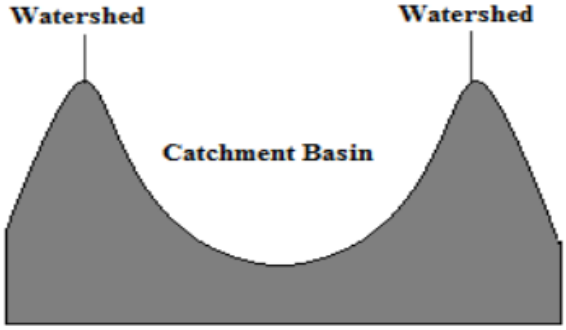


Fig.2 Watershed segmentation-local minima of gray level yield catchment basins, local maxima define the watershed lines

A. Mathematical Background of Watershed Algorithm

Assume, Mi where i= 1 to n be the set of coordinates points in the regional minima (catchment basins), of the image P(x,y) and C(Mi) be the coordinates points of catchment basins associated with the regional minima Mi

Tn ={(s,t)|P(s,t)<n}

Where,

T[n] = set of points in P(x,y) which are lying below the plane p(x,y) = n,

min, max = minimum or maximum gray level value

n = stage of flooding varies from min + 1 to max + 1

Let Cn(M1) be the set of points in the catchment basin associated with M1 that are flooded at stage n.

Cn (M1)=∩{C(M1), T[n]}

Where,

$$Cn(Mi) = \begin{cases} 1 \text{ if } (x,y) \epsilon C(Mi) \text{and } (x,y) \epsilon T(n) \\ 0 \qquad\qquad \text{otherwise} \end{cases}$$

C[n] is the union of flooded catchment basin portions at the stage n.

Where,

C[n] = Cn(m1) U Cn(m2)...Cn(mR)

C[max+1] = C(m1) U C(m2)...C(mR)

If the algorithm keeps on increasing flooding level then Cn(Mi) and T[n] will either remain constant or increase. Algorithm initializes C[min+1] = T[min+1] and then precedes recursively by assuming that at step n, C[n-1] has been constructed.

Let, G is a set of connected components in T[n] and for each connected component g€ G[n], there possibilities will arise.

g∩ C[n-1] is empty.

g∩ C[n-1] contains one connected component of C[n-1].

g∩ C[n-1] contains more than one connected component of C[n-1].

V. Proposed Scheme

In image segmentation, edge detection plays as a very important role. Laplacian of Gaussian (LoG) edge detector is a convolution filter that is used to highlight edges of different objects. 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. We have tried for a new approach on marker controlled watershed algorithm for obtaining better result and less over-segmentation. A modified 9x9 mask of Laplacian of Guassian operator has been presented in this paper. This modified mask is as shown in figure (3).

The flowchart of the proposed approach is given in figure (4). In the present study, the images obtained from the real life have been tested to find the gradient image with the proposed LoG filter and subsequently applied watershed as a segmentation function. In this stage, we can easily see many over-segmented regions that are not suitable in subsequent tasks. To reduce over segmented region, a solution can be achieved by using Marker controlled watershed segmentation. In preprocessing step, as the initial stage, a color image from the real life is chosen and read with MATLAB editor using 'imread' function. The next step is converting the color image into grayscale or black and white image using 'rgb2gray'. Then, the gradient image is resulted from the gray level image with the help of proposed modified mask of LoG. The gradient image can directly apply to watershed segmentation. In segmentation step, watershed algorithm is applied for finding initial segmentation map and the image is analyzed the result (over-segmentation). Then, the external markers using distance transform are enumerated and for smooth edges compute extended regional minima. As the final step, the internal markers are computed and apply the watershed transform and visual the result. The segmented output is more pleasing without over-segmentation and the algorithm is also less time complex than other conventional algorithms.

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

Fig. 3 Modified 9x9 mask

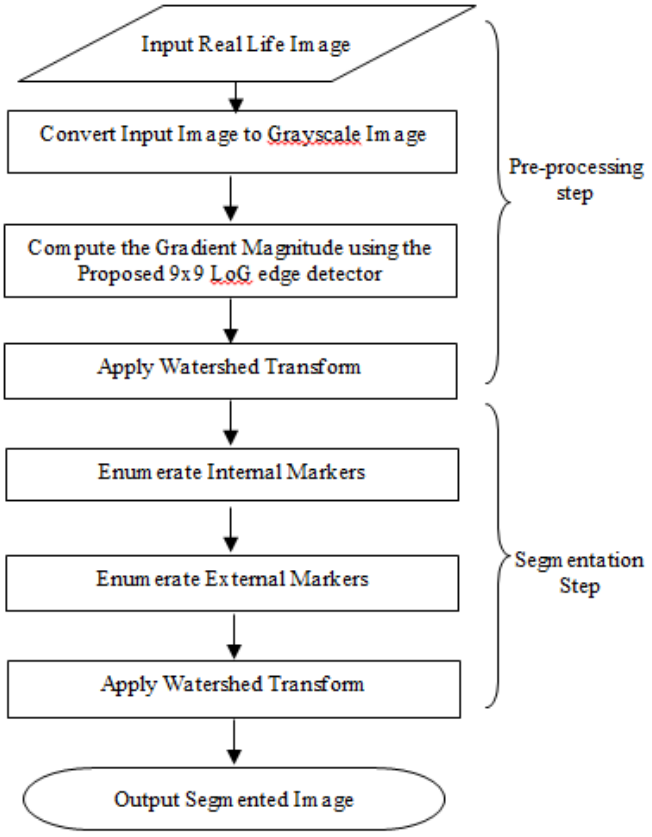


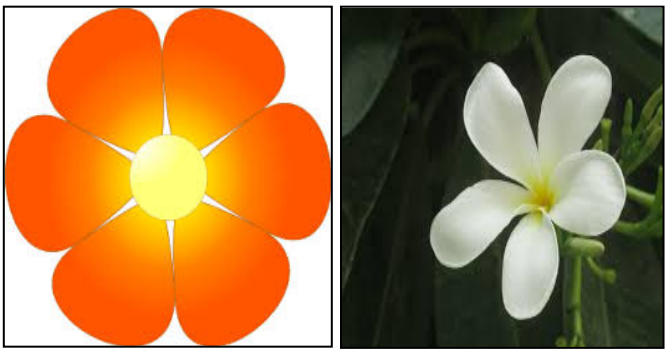
Fig. 4 Flowchart of Proposed System

VI. Results 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. Fig (5) displays the original colorful image.

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 (6) displays the gradient

image that has been observed with the proposed system.



(A) (B)

Fig5. Original real life images

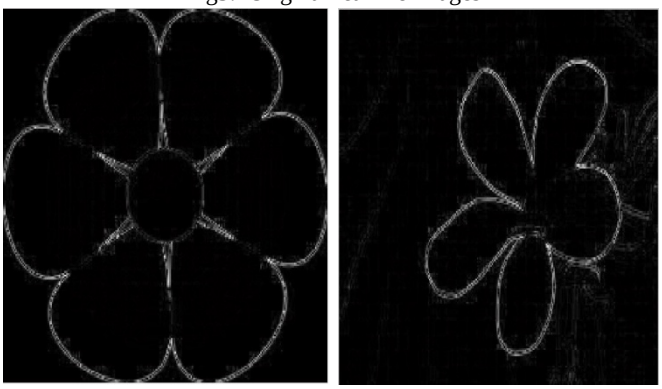


Fig6. Gradient images obtained by modified 9x9 LoG filter

After that, the gradient image which obtained by using 5x5 LoG filter mask is segmented with conventional watershed transform .There has found over segmented regions as shown in figure(7). It results an unacceptable segmented image. Figure (8) depict over-segmented image that are obtained by watershed segmentation with 9x9 LoG filter. In order to get better result, these over segmented regions must be processed with marker-controlled watershed transform.

We can easily seen by comparing with the segmented images of modified 9x9 Log mask as shown in figure 9 and 10 respectively that conventional 5x5 Log edge detector have produced pale edges (i.e, the edges in image are not very sharp). Therefore, in practice, these gradient images can affect the segmented images in the next step. On the other hand, we have been found that modified LoG filter can give more enhance gradient images than conventional LoG filter. Thus, it results less over segmented image and gets better final segmented image.

In this case, 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 5x5 LoG mask in figure 7 and 8 respectively have been found extremely over segmented regions. Over segmentation is a very difficult problem in watershed segmentation. However, the proposed filter can be optimized the segmented image by following marker-controlled watershed segmentation.

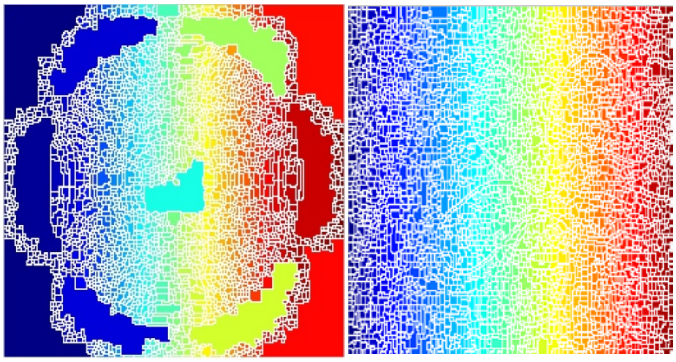


Fig.7 Over segmented Image obtained by Watershed Segmentation with 5x5 LoG filter

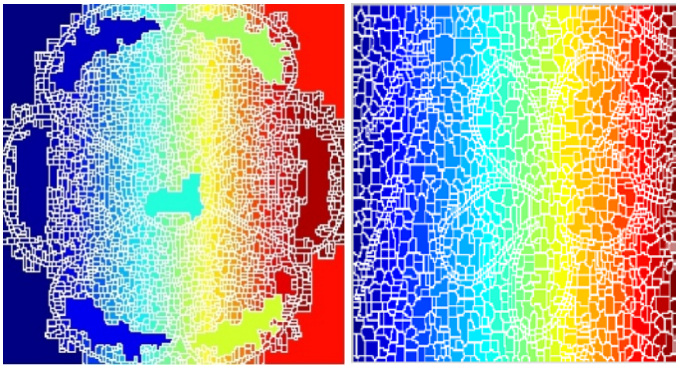


Fig.8 Over segmented Image obtained by Watershed Segmentation with 9x9 LoG filter

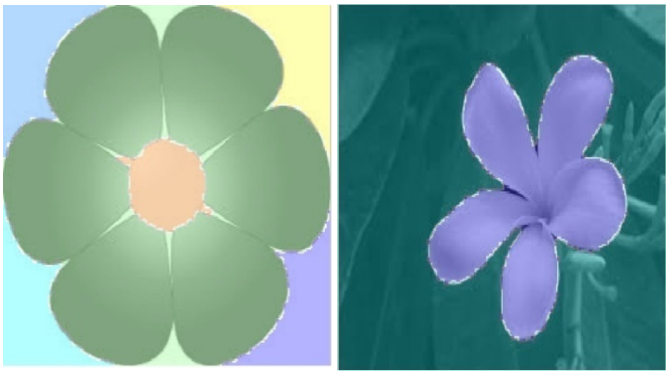


Fig.9 Superimpose transparently on original color Using Marker-Controlled Watershed Transform image obtained by 5x5 LoG filter)

The entropies of the final segmented images using marker controlled watershed segmentation through 5x5 LoG filter and 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.

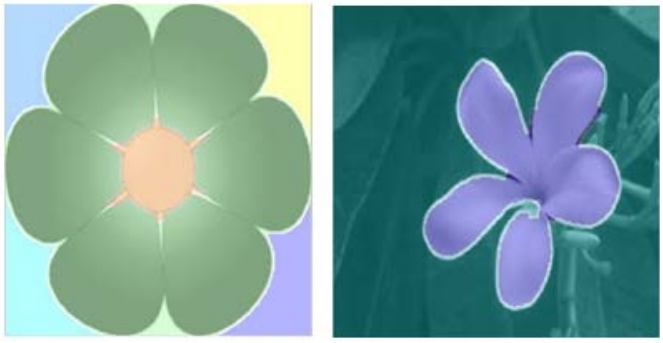


Fig.10 Superimposed transparently on original color Using Marker-Controlled Watershed Transform image obtained by 9x9 LoG filter

TABLE I
ENTROPY VALUES OF SEGMENTED IMAGES AFTER PROCESSING MARKER CONTROLLED WATERSHED SEGMENTATION

Figure	Entropy value of Segmented Image Obtained by Marker Controlled Watershed Segmentation and 5x5 LoG	Entropy value of Segmented Image Obtained by Marker Controlled Watershed Segmentation and 9X9 LoG
Figure (A)	1.3813	1.3559
Figure(B)	0.9762	0.9724

VII. CONCLUSION

Image Segmentation is one of the important fields of image processing and computer vision. Segmentation accuracy determines the success or failure of computerized analysis procedure. The goal of image segmentation process is to identify the segments of the image according to the characteristics of objects e.g. object shape, image color etc. We have proposed a very simple methodology to control over segmentation for the natural images. A solution to reduce over segmentation problem is the use of marker controlled watershed transform. A preprocessing method with modified LoG edge detector performs to reduce the noise of image and adjust the image intensity. The proposed method with LOG filter can make to be better localization when the edges are not very sharp. The presented method has been found to yield better output in term of image quality, clarity and sharpness. As a result of marker controlled watershed, over segmentation problem from conventional watershed can be avoided. Therefore, this system can be very helpful for image segmentation to detect an accurate image clearer. The input images are also provided with the less number of segments and therefore, the presented approach can give the meaningful and acceptable results in image segmentation.

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Khin Lay Mon is a Ph.D. student in the University of Computer Studies, Mandalay, Myanmar. She got M.C.Tech from University of Computer Studies, Mandalay since 2009. Her research interests mainly focus on Digital Image Segmentation and Computer Vision. To support such research goals, her research activities primarily include image segmentation , edge detection, marker controlled watershed.