Edge Detection with Watershed Algorithm for Digital Image Using Fuzzy Logic

Pinaki Pratim Acharjya, Dibyendu Ghoshal

Abstract— Image segmentation and edge detection refers to the process of identifying and locating sharp discontinuities in an image. In this paper a method that integrates fuzzy logic and watershed segmentation algorithm using distance transform for digital image segmentation has been proposed. The proposed method has been applied to a digital image and better performance measure of contour detection has been achieved compared with conservative watershed method.

Index Terms— Edge detection, fuzzy logic, distance transform, watershed algorithm.

1 INTRODUCTION

IMAGE segmentation [1], [3] and edge detection is a vital method for analysis tasks. Edges in digital images are areas with strong intensity contrasts and a jump in intensity from one pixel to the next can create major variation in the picture quality. Over the years, several methods have been proposed for the image segmentation and edge detection. In recent days the watershed segmentation technique [4], [5], [6] has been widely in use. The method originated from mathematical morphology that deals with the topographic representation of an image. A good number of works has already been carried out on watershed segmentation and these are available in the published or online literature [4], [5], [6], [7], [8], [9]. Unfortunately, the watershed segmentation technique leads to an over segmentation problem [10]. Over segmentation is the process by which the image being segmented into small segments [11]. These small segments are usually uniform in size and commonly referred to as super pixels. Over segmentation through extracts important boundaries, may lead to creating insignificant boundaries. In this paper, in order to overcome such problem, a new approach is proposed with the use of fuzzy logic to the watershed algorithm using distance transform. The contemporary Fuzzy logic [12], [13], a key concept of artificial intelligence helps to implement the fuzzy relative pixel value algorithms and helps to find and highlight all the edges associated with an image by checking the relative pixel values and thus provides an algorithm to abridge the concepts of digital image processing and artificial intelligence. In proposed approach first fuzzy edge detector [14] is used followed by morphological smoothing operation [15], [16] and then the watershed algorithm using distance transform [17] is applied on the resultant image. The method helps to detect edges in a digital image with less over segmentation in all cases. The purpose of this paper is to present a new methodology for image edge detection which is undoubtedly one of the most important operations related to computer vision. If the edge detection step is successful, the subsequent task of interpreting the information contents in the original image may therefore be substantially simplified. It has been already found that the lower scale of over segmentation will enable the computers to process the segmented images more easily. The experimental results run on a digital image, showed the effectiveness of the proposed algorithm and the experimental result presented in this paper is obtained by using MATLAB.

The structure of this work is the following: Section 2 introduces the fuzzy approach that has applied with watershed. Section 3 is devoted to the segmentation process for edge detection with watershed algorithm using distance transform. Section 4 presents the proposed scheme. The experimental results and comparison of conservative

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watershed method with the proposed scheme are discussed in section 5 and we finish this paper with some concluding remarks with section 6.

2 FUZZY APPROACH

Edges in images are constituted significant gray level changing. So, for the fuzzy edge detection it has to be white for those pixels which belong to a uniform region and else it will be black, where black and white are fuzzy variables. For uniform region concept, it can be considered that the intensity differences between the pixel at the center of the neighborhood and its neighbors.

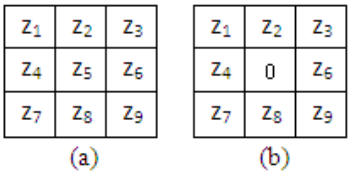

Fig 1. (a) A 3x3 pixel neighborhood, and (b) corresponding intensity differences between the center pixels and its neighborhoods.

As an example with 3x3 neighborhoods in figure 1(a), the differences between the center pixel which is labeled as z_5 and each of the neighbors form the sub image of size 3x3 in figure 1(b), where d_i denotes the intensity differences between the ith neighbor and the center point. The following IF-THEN rules and ELSE rule implement the fuzzy statement mentioned above.

If d_2 is zero AND d_6 is zero THEN z_5 is white

If d_6 is zero AND d_8 is zero THEN z_5 is white

If d_8 is zero AND d_4 is zero THEN z_5 is white

If d_4 is zero AND d_2 is zero THEN z_5 is white

ELSE z_5 is black

In the above rules zero is fuzzy also. The resultant of each rule defines the values to which the intensity of the center pixel is mapped that is z_5. The statement "THEN z_5 is white" means that the intensity of the pixel situated at the center of the neighborhood to white. In a fuzzy sense the rules state that the center pixel is considered to be part of a uniform region if the intensity differences just mentioned are zero. Otherwise (ELSE) it is considered as a black pixel which is considered as boundary. In below Graphical representations of the rules stated above are mentioned. Where, ZE is the range of the independent variable of the fuzzy set. The box leveled z_5 indicates that the intensity of the center pixel is mapped to the output value WH (white) or BL (black).

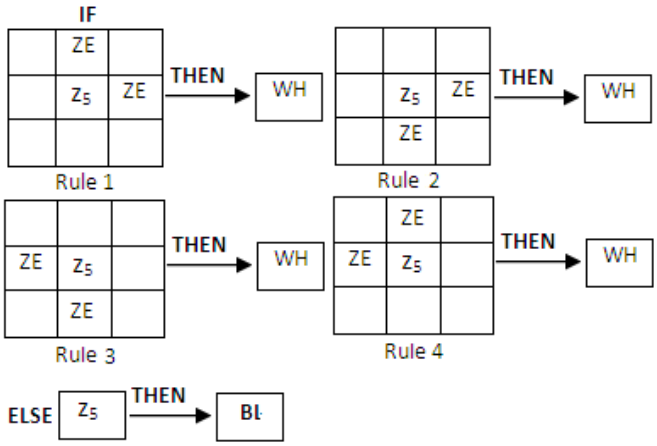

Fig 2. Graphical representation of the rules stated above.

3 WATERSHED ALGORITHM

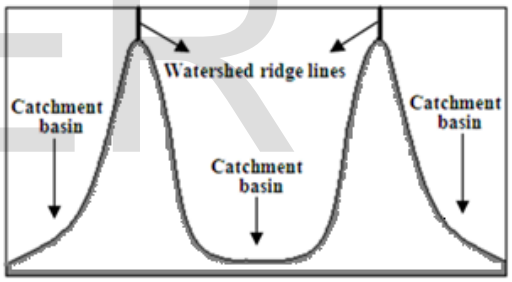

Fig 3. Watershed segmentation-local minima yield catchment basins; local maxima define the watershed lines.

Watershed algorithm is a tool for morphological image segmentation. A gray scale image can be interpreted as the topographic image of landscape. This is accomplished (the image intensity) as an altitude. Using the features of these images, the technique of digital image processing called Watershed Transform. It consists in placing a water source in each regional minimum (catchment basins), to flood the relief from sources, and build barriers when different sources are meeting. The resulting set of barriers constitutes a watershed by flooding, i.e., the set of pixels along which the gray levels changes sharply gives rise to a watershed edge.

For digital image segmentation, the distance transform method is commonly used in conjunction with the watershed

transform. The distance transform is the distance from every pixel to the nearest pixel of a binary image. In distance transform method every 1-valued pixel has a distance transform value of 0 because its closest nonzero pixel is itself. In below, figure 4(a) shows a binary image matrix, and in figure 4(b) shows the corresponding distance transform.

1	1	0	0	0
1	1	0	0	0
0	0	0	0	0
0	1	1	1	0

(a)

0.00	0.00	1.00	2.00	3.00
0.00	0.00	1.00	2.00	3.00
1.00	1.00	1.41	2.00	2.24
1.41	1.00	1.00	1.00	1.41
1.00	0.00	0.00	0.00	1.00

(b)

Fig 4. (a) shows a binary image matrix, and (b) shows the corresponding distance transform.

4 THE PROPOSED APPROACH WITH THE COMPOSITION OF FUZZY RELATIONS AND WATERSHED

In conservative watershed method first gray scale image is obtained from a color image and watershed algorithm is applied on that gray scale image to obtain the final segmented image.

In the proposed scheme, in initial stage a color image is converted into gray scale or black and white image and two new phase has been added before applying the Watershed algorithm using distance transform. First phase is considered as a preparation phase that detects the edges with fuzzy relations. The application of fuzzy conditions on the image helps to highlight all the edges associated with it but do leave unnecessary pixel values. To overcome this, the second phase that is smoothing technique is applied on the fuzzyfied image, followed by watershed algorithm using distance transform to enhance the output or final segmented image. This new approach is able to eliminate all the noisy pixels and filters out the edges to provide us with a clean output image with less over segmentation. The flowchart of the proposed scheme is given in below.

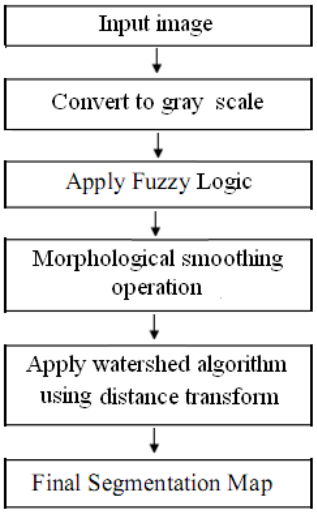

Fig 5. Flow diagram of proposed method.

5 COMPARISON OF CONSERVATIVE WATERSHED METHOD WITH THE PROPOSED SCHEME

The proposed approach is applied on a natural image shown in figure 6. The resultant or segmented images by using conservative watershed method and by using proposed approach are shown in from figure 7 to figure 8 respectively. We obtained output images that consist of all edge information and regions about the objects of input image. It have been observed by comparing the resultant images that the segmented images with conservative watershed algorithm (figure 7) produces over segmentation and also the edges in the images are not very sharp. However the segmented image obtained by using the proposed approach with the composition of fuzzy relations and watershed algorithm using distance transform produces much better, accurate and sharp edges of different objects with less over segmentation.

Fig 6. Original image of Lena.

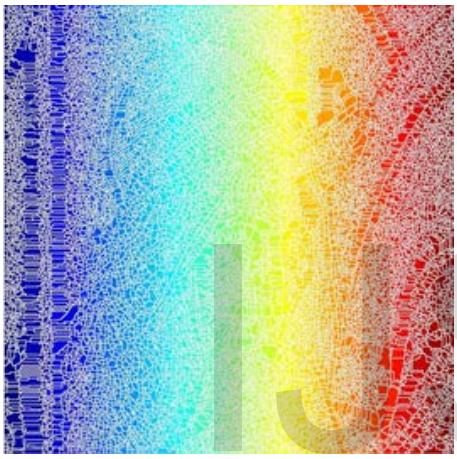

Fig 7. Segmented image with conservative watershed method.

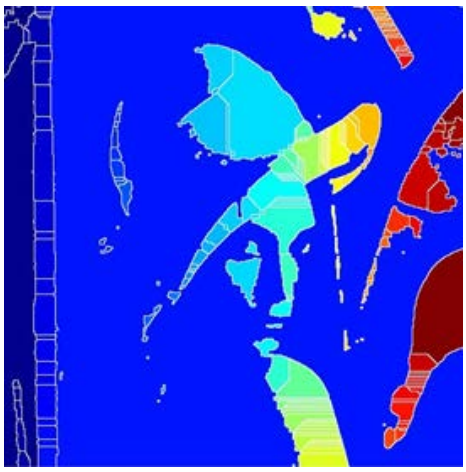

Fig 8. Segmented image with proposed method.

Statistical measurements with entropy, which is a statistical measure of randomness that can be used to characterize the texture of the input image, PSNR (Peak Signal-to-Noise Ratio) where a higher PSNR generally indicates that the reconstruction is of higher quality and mean squared error of the final segmented images using conservative watershed algorithm and using proposed method have been calculated and the values have been shown in the table 1.

TABLE 1
Statistical measurement

IMAGE	ENTROPY	PSNR	MSE
Segmented image with conservative watershed method	5.167	7.4413	1.1721e+004
Segmented image with proposed method	3.508	7.6227	1.1241e+004

6 CONCLUSION

The present work introduced the concept which integrates fuzzy logic and watershed segmentation algorithm using distance transform for digital image segmentation and edge detection. It overcomes the limitations of the conservative watershed algorithm, which include over segmentation. The experimental results had shown that the proposed method has been found to yield better output in term of image quality, clarity and sharpness with the avoidance of over segmentation.

DEDICATION

One of the others (Dibyendu Ghoshal) dedicates the entire study to the loveliest and loving memory of his only one and younger sister Kumari Sumita Ghoshal who herself was a gem of the scholars, a symbol of wisdom and art, peerless beauty and simplicity, unfathomable knowledge and generosity.

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