An Efficient Image Segmentation Approach through Enhanced Watershed Algorithm

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Abstract - Image segmentation is a significant task for image analysis which is at the middle layer of image engineering. The purpose of segmentation is to decompose the image into parts that are meaningful with respect to a particular application. The proposed system is to boost the morphological watershed method for degraded images. Proposed algorithm is based on merging morphological watershed result with enhanced edge detection result obtain on pre processing of degraded images. As a post processing step, to each of the segmented regions obtained, color histogram algorithm is applied, enhancing the overall performance of the watershed algorithm.
Keywords – Segmentation, watershed, color histogram

I. INTRODUCTION

Image segmentation is vital step in the process of image processing. Image segmentation is to divide an image into number of regions so that each region gives information about an object or area of interest [1]. It partitions an image into a set of non overlapping regions whose union is the entire image. The purpose of segmentation is to decompose the image into parts that are meaningful with respect to a particular application, very much like the idea of separating figure from ground.

The image properties consist of:

- Intensity values from original images, or computed values based on an image operator
- Textures or patterns, unique to each type of region
- Spectral profiles that provide multi-dimensional image data

Elaborate systems may use a combination of these properties to segment images, while simpler systems may be restricted to a minimal set on properties depending of the type of data available.

Most segmentation techniques are either region-based or edge based.

• *Region-based* techniques rely on common patterns in intensity values within a cluster of neighboring pixels. The cluster is referred to as the region, and the goal of the segmentation algorithm is to group regions according to their anatomical or functional roles.

•*Edge-based* techniques rely on discontinuities in image values between distinct regions, and the goal of the segmentation algorithm is to accurately demarcate the boundary separating these regions.

II. LITERATURE REVIEW

The watershed algorithm is one of the most powerful morphological tools for image segmentation.

Hao Wei et al [10] presented an improved watershed algorithm for medical image segmentation. Firstly, an iterative data-adaptive Gaussian smoother is used to smooth large scale details while suppress noises. Secondly, the contour information of the original image is enhanced and revised by fusing the gradient with the detected edges. Finally, valley-filling technique is used to control the number of the resultant watershed regions.

A new image segmentation based on reconstruction labeling watershed algorithm in color space [11] is proposed which converts the RGB color image into a new color space image, and calculate gradients. Object regions are extracted to compose a binary marked image through the use of morphological opening and closing reconstruction, and gradient image is introduced for substituting the marked image. Finally, the watershed transformation is carried out in the modified gradient image. This not only can overcome over-segmentation but also retains the edge information of the object as much as possible.

Zhonglin et al [12] worked to obtain the size of contamination area of the insulator. They segmented the insulator image with water-shed algorithm, and then the region growing algorithm was applied to process the segmented image, which can guarantee the segmentation effectiveness and reduce the number of segmented regions so as to enhance the segmentation results of the insulator image.

Jie Chen et al [13] discuss an image reconstruction and segmentation in an improved watershed algorithm by using a plug-in function in flooding process. This extends the watershed transform for segmentation by allowing the integration of a priori information about image objects into flooding simulation processes. Their method can customize the initial seeding, region growing and stopping rules of the watershed flooding process according to user-defined functions incorporating prior information.

Their method shows very low error rates compared with the recent literature and in comparisons with other algorithms, while being easily adapted to new imaging contexts.

Shang et al [14] adopts a multi-resolution analysis theory, using wavelet trans-formation theory establishment multi-resolution analysis framework on image segmentation. Multi-wavelet transform has some unique advantages and good performance on edge detection and texture analysis. Their research uses multi-wavelet transform to improve the over-segmentation

watershed transformation, to get meaningful image segmentation result.

III.WATERSHED TRANSFORMATION

The idea of watershed transform is straightforward by the intuition from geography. The main goal of watershed segmentation algorithm is to find the "watershed lines" in an image in order to separate the distinct regions [9]. To imagine the pixel values of an image is a 3D topographic chart, where x and y denote the coordinate of plane, and z denotes the pixel value. The algorithm starts to pour water in the topographic chart from the lowest basin to the highest peak. In the process, we may detect some peaks disjoined the catchment basins, called as "dam". The watershed algorithm is one of the most powerful morphological tools for image segmentation.

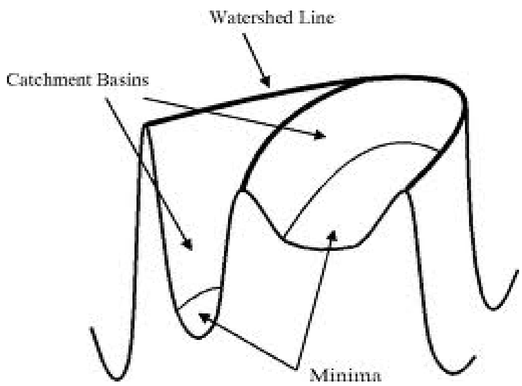

Figure 1: Catchment basin and Watershed line

The watersheds may be obtained in two ways, either the boundaries of segmented regions, or the complement of segmented regions. Beucher [2] categorized watershed algorithms into two groups. The algorithms in the first group like immersion algorithm [3] simulate the flooding process. The immersion algorithm is one of the most famous watershed segmentation algorithms. It offers an efficient way to extract watershed lines by simulating the immersion process on gradient images. The second group of watershed algorithms aims at direct detection of watershed lines.

Unlike the typical morphological filters, the watersheds transformation is not composed of the primitive morphological operations. The initial concept of the watersheds transformation as a morphological tool was introduced by H. Digabel and C. Lantuéjoul in [4]. Later, a joint work of C. Lantuéjoul and S. Beucher led to the 'inversion" of this original algorithm in order to extend it to the more general framework of grayscale images. Later, watersheds were studied by many other researchers and used in numerous grayscale segmentation problems. In this proposal, the efficient algorithm for watersheds suggested by Luc Vincent and Pierre Soille [5] is reviewed briefly and used throughout the entire simulation.

Embedded Problems in Watershed Segmentation

The watersheds transformation is an effective method for extracting out continuous boundaries of each region and gives solid results. However, applying it to the original image can cause undesired results.

(i) Oversegmentation

The watersheds transformation makes a number of regions as an output. For eg, a human can clearly see a woman with background in Figure 2. This is because humans are capable of understanding the 'semantics' of a given scene; however, this image has 2976 different regions after the watersheds transformation.

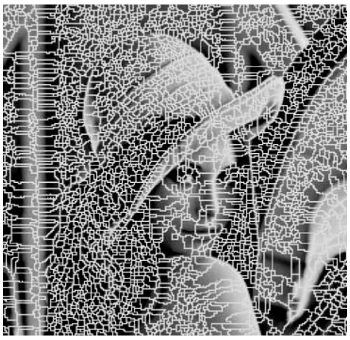

Figure 2: An Example of the Watersheds transformation on Gray-scale Image

This oversegmentaion problem comes mostly from the noise and quantization error. To eliminate the effect of local minima from noise or quantization error on the final results, first, the gradient of the original image is computed as a pre-processing and then the watersheds transformation is applied on the gradient of image. Another approach is to apply a post-processing where a large number of regions are merged until the output meets a given criteria which can be the number of regions or a dissimilarity value between homogeneous regions.

(ii) Ambiguous Boundary on Homogeneous Regions.

Another reason why the watersheds transformation is applied to the gradient image is because the watersheds transformation makes ambiguous boundaries occasionally. Figure 3 shows a simple case with a vague boundary. As interpreted, it consists of 3 different homogeneous regions. If the watersheds transformation is applied directly to the original image, then the output is just 2 different regions. The only marked boundary is made across the middle homogeneous regions. It does not match the original boundaries.

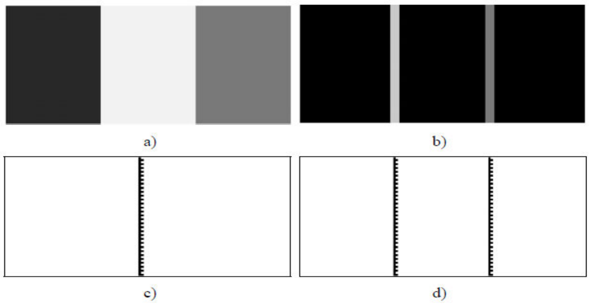

Figure 3: Simple Illustration of Ambiguous Boundary Extraction:
(a)original, b) gradient, c) WS on original, d) WS on gradient

However, if the transformation is applied to the gradient of the original image, it can extract out proper boundaries and recognize 3 different homogeneous regions.

IV. INTRODUCING THE CONCEPT OF COLOR HISTOGRAM

The JND color model in RGB space based on limitations of human vision perception as proposed in [6] is briefed here for ready reference. The human retina contains two types of light sensors namely; rods and cones, responsible for monochrome i.e. gray vision and color vision respectively. The three types of cones viz, Red, Green and Blue respond to specific ranges of wavelengths corresponding to the three basic colors Red, Green and Blue. The concentration of these color receptors is maximum at the center of the retina and it goes on reducing along radius.

According to the three color theory of Thomas Young, all other colors are perceived as linear combinations of these basic colors. According to [7] a normal human eye can perceive at the most 17,000 colors at maximum intensity without saturating the human eye. In other words, if the huge color space is sampled in only 17,000 colors, a performance matching close to human vision at normal illumination may be obtained. A human eye can discriminate between two colors if they are at least one 'just noticeable difference (JND)' away from each other. The term 'JND' has been qualitatively used as a color difference unit [8].

(a) Computing the Basic JND Histogram

Using this sampling notion and the concept of 'just noticeable difference' the complete RGB space is mapped on to a new color space J_r J_g J_b where J_r, J_g and J_b are three orthogonal axes which represent the Just Noticeable Differences on the respective R,G and B axes. The values of J on each of the

color axes vary in the range (0,24) ,(0,26) or (0,28) respectively for red, blue and green colors. This new space is a perceptually uniform space and offers the advantages of the uniform spaces in image analysis.
Histogram of an image manifests an important global statistics of digital images, which can be used for a number of analysis and processing algorithms. In color image histograms, a large number of colors may be present as required for representing real life images. All of these colors may not even be noticed as different colors by normal human eye [8], hence as the first step the histogram on each of its axis has been sampled suitably to accommodate all the human distinguishable colors.

(b)Histogram Agglomeration and Segmentation

Agglomeration in chemical processes attributes to formation of bigger lumps from smaller particles. In the digital image segmentation, the similar pixels (in some sense) are clustered together under some similarity criteria. And thus it was inspired that the agglomeration may contribute considerably in the process of color image segmentation. The agglomeration techniques can be thought of as the powerful alternatives to the other image thresholding techniques. After the compressed histogram of a real life image is obtained using the basic JND histogram algorithm, the agglomeration technique can further be used to reduce the number of colors by combining the smaller segments with similar colored larger segments. This helps in minimizing over segmentation.

V. PROPOSED WORK

Proposed algorithm is based on merging morphological watershed result with enhanced edge detection result obtain on pre processing of degraded images. Here preprocessing means image restoration. Hence it enhances the watershed result. Color Histogram algorithm is applied to each of the segment as a post processing step which further enhances the overall result.
The proposed segmentation algorithm is schematically illustrated in the block diagram shown below.

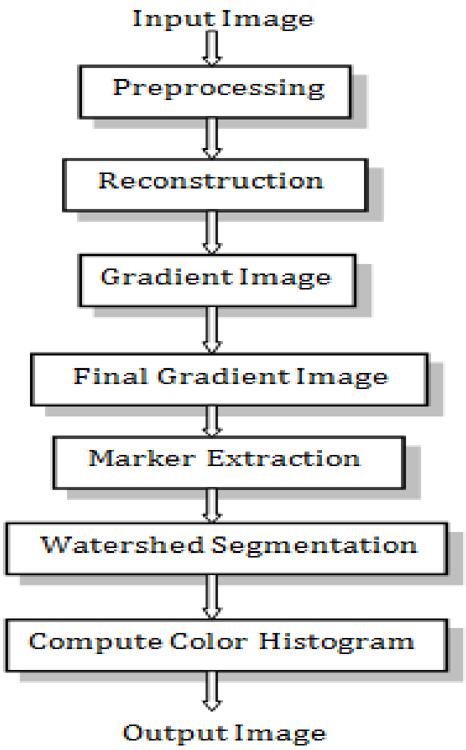

Figure 4: Flow chart of proposed work

Description of each block

(a) Input image (Degradation model)

In degradation model, the image is blurred using filters and additive noise via Gaussian Filter and Gaussian Noise. Gaussian Filter represents the PSF which is a blurring function. The degraded image can be described by the following equation

$$g = H*f + n$$

g is degraded/blurred image, *H* is space invariant function (i.e.) blurring function, *f* is an original image, and *n* is

additive noise.
Image deblurring can be done by the convoluting the image with 2-D Gaussian function.

(b) Canny edge detection and ringing effect

The Discrete Fourier Transform used by the deblurring function creates high frequency drop-off at the edges of images. This high frequency drop-off can create an effect called boundary related ringing in deblurred images. For avoiding this ringing effect at the edge of image, we have to detect the edge of an image. The edge can be detected effectively using Canny Edge Detection method. It uses two different thresholds foe detecting both strong and weak edges.

(c) Preprocessing

In preprocessing block we do image restoration i.e recovering the original image from the degraded image. Blind Deconvolu-tion algorithm is applied to the blurred image. It is possible to renovate the original image without having specific knowledge of degradation filter, additive noise and PSF.

(d) Morphological Reconstruction

The preprocessed image is morphologically reconstructed for smoothening the interior of the objects and to preserve the boundary of the objects. The objects to be smoothened are subjected to a group of morphological operators.
The basic morphological operators involved in this phase are *dilation* and *erosion*.

(e) Gradient Image Generation

The local gray-level variation in the image can very well be given by the morphological gradient. A gradient helps detecting ramp edges and avoids thickening and merging of edges providing edge-enhancements. The gradient image, *G(f)* is morphologically obtained by subtracting the eroded image, ε *(f)* from its dilated version, *∂(f)* .

(f) Marker Extraction

Markers can be used to solve the over-segmentation problem whose goal is to detect the presence of homogeneous regions from the image by a set of morphological simplifications. The Markers are connected components belonging to an image, internal markers are inside each of the objects of interest and external markers are contained within the back-ground. The resulting marker image *M(f)* is a binary image such that a pixel is a marker (to be black) if it belongs to a homogeneous region, a pixel will be white if it does not belongs to homogeneous regions.

(g) Image Segmentation

The Final Gradient image which is marker extracted is subjected to Watershed Segmentation. Watershed segmentation produces a more stable segmentation of objects including continuous segmentation boundaries by a concept of producing catchment basin and watershed line. Watershed and watershed lines are those points in a topographic surface where a water drop placed would definitely fall into a single minimum and are equally likely to fall in one or more of minimal points respectively.

(h) Computing Color Histogram

To each of the segmented regions obtained, color histogram algorithm is applied i.e computing the JND histogram followed by the agglomeration of the histograms which can be thought of as the powerful alternatives to the other image thresholding techniques. After the compressed histogram of an image is obtained using the basic JND histogram algorithm, the agglomeration technique can further be used to reduce the number of colors by combining the smaller segments (less than .1% of the image size) with similar colored larger segments. This stimulates the process of merging of small left over segments with larger similar segments.

VI. RESULTS

Table of parameters

Result computed is analysed in terms of three parameters namely-
DSC (Dice Similarity Coefficient) is a measurement of spatial overlap used widely for comparing segmentation results, which can have a value ranging from zero to one. *Precision* and *recall* is propotional to the total number of unmatched pixels between two segmentations S1 and S2. *Precision* (P), defined as the fraction of detections that are true boundaries and *Recall* (R), given by the fraction of true boundaries that are detected. Thus, Precision quantifies the amount of noise in the output of a detector, while Recall quantifies the amount of ground-truth detected.

Parameter	Watershed Algorithm	Color Histogram	Proposed Method
DSC	0.701595	0.413567	0.964047
Precision	0.82432	0.748208	0.897597
Recall	0.556199	0.494198	0.663132

Table 1. Comparative Result

Fig 5(a)Original image (b)Segmented image

VII. CONCLUSION

Image segmentation is a vital step in image processing. The purpose of image segmentation is to divide the original image into homogeneous regions. There are several approaches to perform this task such as *Edge-based, Clustering-based, Region-based, etc. In this work the watersheds transformation was selected as a particular region-based approach method to do the segmentation. The immersion process of the watersheds transformation is a fast and powerful algorithm to produce the segmented image. The transformation needs pre-processing and post-processing for embedded problems.*

The evaluation of the segmentation is done by comparing the each object in true segmentation with the object in marker-controlled watershed segmentation or proposed method. Conclusion is that the proposed method enhances the result of marker-controlled watershed for degraded images. Here the enhancement is in terms of robustness i.e. the outcome and accuracy. For example if watershed algorithm identifies three objects from an image containing six objects. Then proposed system will try to identify four or five object from the same image containing the six objects. The restoration and segmentation quality of the proposed method was visually and quantitatively better than those of the other algorithms. The segmented output is more pleasing without over-segmentation and the algorithm is also less time complex than other traditional algorithms.

VIII. FUTURE SCOPE

The domain of image segmentation is still immature. Many unsettled problems need to be defined and solved in this area. It is firmly believed that this domain will greatly advance in the future

Following are the suggestions for future scope.

1. Improve the speed by using parallel processing either on clusters system or multiprocessor system.
2. Merge this technique with some other technique to get the better results.
3. Various soft computing techniques can be used to have better result.

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