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A Watershed Segmentation Process based on Progressive Median Filtering & Gradient Map

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***Abstract*—In this paper, we present a digital image segmentation algorithm that is effective and offers robustness while minimizing the over segmentation issues. The proposed algorithm is designed to use the combination of Median-filtering, soft thresholding and watershed segmentation method, and sobel gradient map was used to perform image segmentation and edge detection tasks. In brief, median filter is performed on the image to limit the problem of undesirable over-segmentation results produced by the watershed algorithm. Soft thresholding is carried based on the region's maximum value to obtain binary segments of various classes to boast the watershed algorithm performance. The gradient map is created based on the edge strength of the image using sobel operators. In addition, the simulations results reveal that the proposed system offers improved segmentation results in comparison with the regular watershed algorithms.**

***Index Terms*—Watershed algorithm, segmentation, media filter, sobel operator, morphological operation.**

I. INTRODUCTION

In the current digital era, automated image processing has established itself as an active research area within the field of image processing. This area is useful for quickly evaluation of large data, but machines are not yet as competent as people. Automated image processing has many military and civilian applications including target identification from satellite imagery, terminal guidance of smart bombs, user authentication for security systems, tumor identification from CAT scans, and blood cell counts from stained microscope slides. Unfortunately, machines do not process images as accurately as humans [1]. Hence forth, the need for an image processing algorithm that could classify or cluster an image into several parts (regions) according to the feature of image. Image segmentation is the process of partitioning an image into non-intersecting regions such that each region is homogeneous and the union of no two adjacent regions is homogeneous. Image segmentation algorithms are used for addressing various issues that arise in many image processing applications to improve efficiency of the algorithm by using optimal resources. It can identify the regions of interest in a scene or annotate the data. We can classify the existing segmentation algorithms into four classes based on the image features employed by the algorithm they are as follows [2]:

1. *Region-based segmentation*: These algorithms expand each region pixel by pixel within in the 8-neighborhood based on quantized value. So that each region thus obtained have homogeneous pixels of similar values with reference to the quantized value.
2. *Data clustering based segmentation*: These algorithms employ that the homogeneous regions are connective in nature. The characteristic of data clustering is based on fact that each pixel of a cluster does not certainly connective in its neighborhood.
3. *Edge-based segmentation*: These algorithms utilize the concept of edge detection or similar frameworks as the markers for segmentation. Some of the commonly used edge detection methods are gradient operators and Hilbert transforms.
4. *Hybrid based segmentation*: These algorithms are proposed based on using two or all three of above mechanisms in a specific order based on the application requirement. Most of researchers are focusing or order and extent to which a mechanism needs to incorporated so that it would time efficient and application effective.

It is a well known fact that the segmentation of nontrivial images is one of the most difficult tasks in image processing. The success or failure of computerized analysis procedures depends on the accuracy of Segmentation process in consideration [3]. For this reason, considerable care and time is being spent to improve the probability and effectiveness of rugged segmentation algorithms. In this paper, we introduce a time domain segmentation framework based on histogram analysis and soft threshold. The proposed system used the two basic properties of the image pixels i.e. discontinuity and similarity in tandem to define the segmentation process within a localized region of digital media. In brief, the proposed approach partitions the image based on abrupt changes in intensity (i.e. background to foreground) based on the histogram analysis. This process is combined with merging of similar regions based on a set of predefined criteria or soft thresholding. The following paper has been organized as follows. In this correspondence, Section 2 describes about various existing segmentation techniques and their limitations in brief. Section 3 introduces in brief regarding watershed algorithm along with its limitations and new preprocessing to reduce the effect of watershed algorithm limitations during the segmentation algorithm. The proposed system and its algorithm are explained in section 4 with detail illustrations. Section 5 deals with the experiments results and the analysis of the proposed segmentation algorithm. Section 6 provides the conclusion of the paper.

II. LITERATURE SURVEY

In this section, we provide a brief background of various existing segmentation techniques. The seeded region growing (SRG) algorithm is one of the simplest region-based segmentation methods. It performs a segmentation of an image with examine the neighboring pixels of a set of points, known as seed points, and determine whether the pixels could be classified to the cluster of seed point or not [4].

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Unfortunately, this method is a time consuming and initial seed point needs to be specified.

Unlike most of supervised and region growing algorithms, fast scanning algorithm do not need seed point. In brief, the concept of fast scanning algorithm [5] is to scan from the upper-left corner to lower-right corner of the whole image and determine if we can merge the pixel into an existed clustering. The merged criterion is based on our assigned threshold. If the difference between the pixel value and the average pixel value of the adjacent cluster is smaller than the threshold, then this pixel can be merged into the cluster.

Lei Li et.al [6] proposed an improved method for color segmentation which uses the FSVM (fuzzy support vector machines) algorithm in the HSI (hue-saturation-intensity) color space. Their system offers better effect and lower computational complexity on color image segmentation than most of existing methods. It was noticed that HSI color system has a good capability of representing the colors of human perception. Unfortunately, the conversions of color space causes loss of valuable and time consuming process on the whole. Wen bing Tao et.al [7] introduced a novel approach that provides effective and robust segmentation of color images. By incorporating the advantages of the mean shift (MS) segmentation and the normalized cut (Ncut) partitioning methods. In addition, they illustrate that the low computational complexity makes their method feasible for real-time image segmentation processing. It also preprocesses an image by using the MS algorithm to form segmented regions that preserve the desirable discontinuity characteristics of the image. Further, this proposed method allows a low-dimensional image clustering with significant reduction of the complexity compared to conventional graph partitioning methods that are directly applied to the image pixels. In addition, the image clustering using the segmented regions reduces the sensitivity to noise and results in enhanced image segmentation performance.

Cheng-Wan An et.al [8] proposed an adaptive segmentation approach for color image in RGB space based on Rival Penalized Competitive Learning (RPCL). Initially, histograms of Red, Green, and Blue component colors are segmented by adaptive threshold segmentation algorithm for gray image. The some possible colors of original image are specified through combining those components' segmented areas and false colors not appearing in image are removed. Finally those possible colors are converged to the main actual colors of original image by RPCL. Then original image is segmented by those learned centers without specifying the number of initial classes in advance. Ming-Xin Zhang et.al [9] proposed conventional image segmentation based on rough-set theory. The new distance matrix is defined by using the vector angle and Euclidean distance. And then according to this new distance matrix, the space binary matrixes of each color component are calculated. Further, the color image segmentation is implemented by selection of threshold values and region merging through introducing a histogram based on roughness. This proposed approach yields better segmentation which is more intuitive to human vision compare with the existing conventional image segmentation.

Chunming Li et.al [10] introduced a new variation level set formulation in which the regularity of the level set function is intrinsically maintained during the level set evolution. Level set is derived as the gradient flow that minimizes energy functional with a distance regularization term and an external energy that drives the motion at desired locations. The distance regularization obtained by a potential function, which is able to maintain a desired shape of the level set function, particularly a signed distance profile near the zero level set. The distance regularization effect eliminates the need for re-initialization and thereby avoids its induced numerical errors. Further, this framework simpler and more efficient finite difference scheme can be used to implement the DRLSE formulation.

Thus to address the limitation of the commonly used existing segmentation algorithms, we design an effective spatial domain segmentation framework based on the watershed algorithm. In addition, the proposed system uses median filter in pre-processing stage to limit the over segmentation of the algorithm. Then the marker contours are generated as a map based on the sobel defined operator.

III. WATERSHED ALGORITHM

It is a well known fact that effective segmentation of complex images is one of the most difficult tasks in image processing. In this section, we introduce watershed algorithm and its application towards image segmentation algorithm. The prime initiative of watershed segmentation algorithm is based on the concept of topographic representation of image intensity. Meanwhile, Watershed segmentation also embodies other principal image segmentation methods including discontinuity detection, thresholding and region processing. Because of these factors, watershed segmentation displays more effectiveness and stableness than other segmentation algorithms.

The prime objective of watershed algorithm is to determine all of the watershed lines (the discontinuity in the image). The most intuitive way to explain watershed segmentation is the *Immersion Approach* [11]: imagine that a hole is drilled in each minimum of the surface, and we flood water into different catchment basins from the holes. If the water of different catchment basins is likely to merge due to further immersion, a dam is built to prevent the merging. This flooding process will eventually reach a stage when only the top of dam (the watershed lines) is visible above the water line.

Further, the much discussed issues surrounding the watershed algorithm are well explained using the figure 1 & 2. Figure 1, shows the original image that would be processed using watershed algorithm to obtain the segmented regions. The figure 2 presents the over segmentation problem associated with the watershed algorithm. In order to limit this drawback, we propose a combination of Median-filtering, soft thresholding and maker controlled pre-process.

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Fig.1 Original image 'Flower'

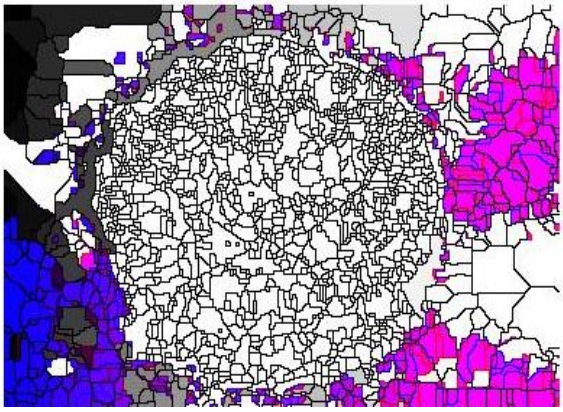

Fig.2 Segmented regions using watershed algorithm

A. *Median Filtering*

Median filtering is a commonly used non-linear operation for simultaneously smoothing the image while preserving its edges, but the side effect is that it also blurs sudden changes (corresponding to high spatial frequencies) such as sharp edges. The median filtering is performed on the image prior to the segmentation process as it would remove any noise in the image and smoothen the image.

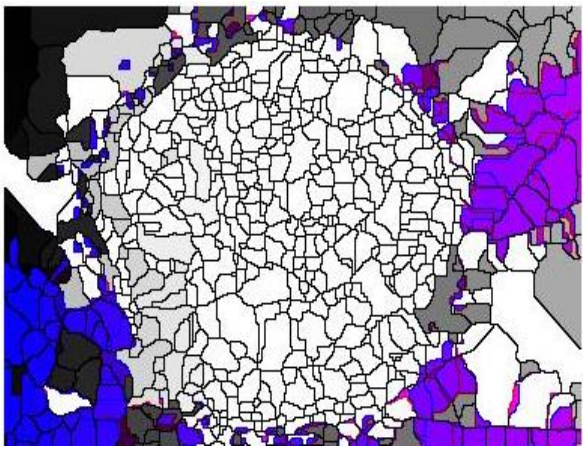

Fig.3 Segmented regions using watershed algorithm after median filtering

In this paper, we employed a simple median filter in a neighborhood of size {3,3} to obtain the desired minimal segmentation. The reduction of the over-segmentation due to watershed algorithm is evident from the figure 3. Each output pixel contains the median value in the 3-by-3 neighborhood around the corresponding pixel in the input image.

$$y[m, n] = \text{median}\{x[i, j], (i, j) \in w\} \quad .. (1)$$

Where, "w" represents a neighborhood that is centered around the location (m, n) within the image of consideration. In addition, the pre-processing could be further improved by designing a similar system as proposed Saurabh Agrawal et al. [12]. They have designed variation measure that is based on the localized statistical calculations that are dependent on median based statistics and varies the size of the mask in consideration.

B. *Soft Thresholding*

Thresholding is one of the oldest, simplest and most popular techniques used in the image processing. Most of the commonly used thresholding techniques literature is concerned with classifying pixels into object or background classes could for instance appear from noise [1]. The simplest way of choosing the threshold value would be a fixed value, based on predefined constraints.

It is well known facts that threshold techniques make decisions based on local pixel information and are effective when the intensity levels of the pixels fall squarely outside the range of levels in consideration. Since the pixel information fall on non-squarely, even with adaptive threshold, it is still difficult to segment some regions with similar properties [13].

We introduce the soft thresholding mechanism to determine the region maxima within the 8-connected neighborhood. Thus the localized region is divided into two homogenous regions under that are defined dynamically based on the size and statistics of the region in consideration. In addition, we also use a global threshold function based on Otsu's method, which chooses the threshold to minimize the intra-class variance of the black and white pixels.

C. *Sobel Operations*

The Sobel operator performs a 2-D spatial gradient measurement on an image and so emphasizes regions of high spatial frequency that correspond to edges. The kernels are designed to respond maximally to edges running vertically and horizontally relative to the pixel grid, one kernel for each of the two perpendicular orientations as presented in the figure 5.

Fig.4 Segmented regions using watershed algorithm after median filtering

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The kernels can be applied separately to the input image, to produce separate measurements of the gradient component in each orientation (call these horizontal gradient *Gx* and vertical gradient *Gy*). These can then be combined together to find the absolute magnitude of the gradient at each point and the orientation of that gradient. The gradient magnitude is given by:

$$|G| = \sqrt{G_x^2 + G_y^2} \qquad \ldots (2)$$

−1	−2	−1	−1	0	1
0	0	0	−2	0	2
1	2	1	−1	0	1

Fig.5 The horizontal (*Gx*) and vertical (*Gy*) masks of the sobel operator

Typically it is used to find the approximate absolute gradient magnitude at each point in an input grayscale image. Technically, it is a discrete differentiation operator, computing an approximation of the gradient of the image intensity function. At each point in the image, the result of the Sobel operator is either the corresponding gradient vector or the norm of this vector. The Sobel operator is based on convolving the image with a small, separable, and integer valued filter in horizontal and vertical direction and is therefore relatively inexpensive in terms of computations. On the other hand, the gradient approximation that it produces is relatively crude, in particular for high frequency variations in the image.

IV. PROPOSED SYSTEM

In this section, we introduce a watershed based segmentation algorithm based on combination of median filtering, soft thresholding and sobel operators concepts discussed in the earlier sections. The general structure of the segmentation process is presented in the Figure 6. The basic components of the proposed segmentation framework are presented as follows

Inputs: - *Input Image.* The cover image may be of any image format using the 8-bit, power of two's representation. The proposed algorithm may also be applied on 24-bit, each color layer images treated as an individual 8-bit image.

Pre-Processing Analysis. The image is converted into gray-scale image by combining RGB components with fixed weights. The median filtering analysis of an image is considered as a smoothing distribution over the pixels values. Further, it provides a means to determine the information content of the image but it would not take spatial factors into consideration. Further, the thresholds should be chosen based on the regional peak values among the image regions.

Gradient Matrix. The gradient matrix is the key feature of the proposed segmentation process as the efficiency of the segmentation process depends on the how accurate the gradient matrix is defined. The aim is to retain as much as edge detail information as possible in the gradient map. This method has the advantage of not having to estimate any parameters, as they are evaluated based on the pre-defined sobel operator. The gradient is high at the borders of the objects and low (mostly) inside the objects.

Soft Threshold based System. Soft threshold based technique is one of the commonly used image processing operation for digital filtering. The proposed system uses the soft thresholding to evaluate each binary label with reference to the input image and calculate the combined homogeneity of the region. In addition, we also use a global threshold function based on Otsu's method, which chooses the threshold to minimize the intra-class variance of the black and white pixels. The topographical distance function to obtain a watershed segmentation which is formulated within the level set theory is also obtained in this phase.

Watershed Algorithm System. Watershed segmentation also embodies other principal image segmentation methods including discontinuity detection, thresholding and region processing. Because of these factors, watershed segmentation displays more effectiveness and stableness than other segmentation algorithms.

Outputs: - Segmented *Image.*

The Segmentation process is a straightforward process where all necessary parameters are dictated based on the combination of median filtering, sobel operation and soft thresholding. Input image is segmented into various uniform and non-uniform regions without any loss or integrity with reference to the input with highest efficiency and low time complexity.

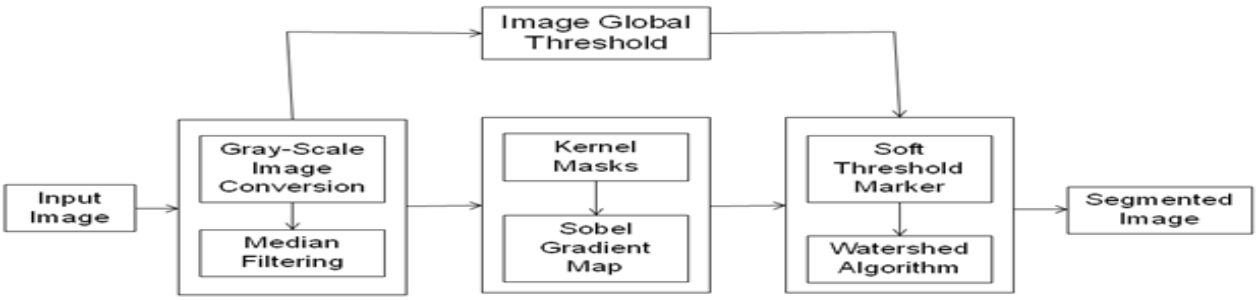

Fig. 6 The basic components of the proposed watershed based segmentation framework

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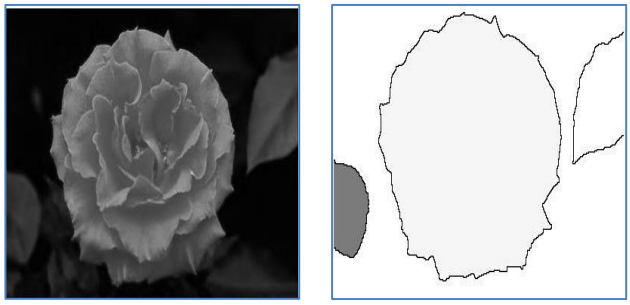
V. COMPUTER SIMULATION

Computer simulations were simulated using MATLAB software package. Analysis was done using 100 color images of varying sizes, texture and contour.

These images were taken using 2 digital cameras Nikon D100 and Canon EOS Digital Rebel and modified in Photoshop to attain a smooth histogram. In addition, for testing the effectiveness and efficiency of the proposed system varying images with different image features are employed

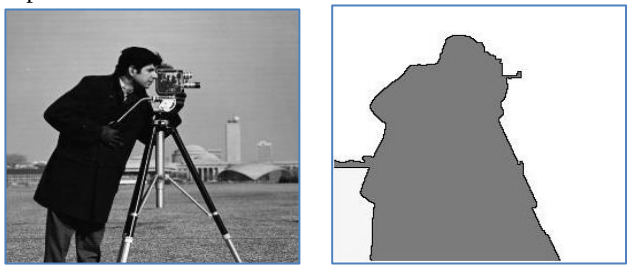
Figure 7 shows the segmentation results of a "flower" image with objects having weak edges. Figure 7(a) shows the input image to our model. The figure 7 (b) shows the segmentation result that is obtained by the proposed watershed framework.



a) b)

Fig.7 (a) Input Image "flower" (b) Objects detected based on proposed segmentation algorithm

Figure 8 shows the segmentation results of a "cameraman" image with objects having weak edges and smooth texture. Figure 8(a) shows the input image to our model. The figure 8 (b) shows the segmentation result that is obtained by the proposed watershed framework



a) b)

Fig.8 (a) Input Image "cameraman" (b) Objects detected based on proposed segmentation algorithm

a) b)

Fig.9 (a) Input Image "pears" (b) Objects detected based on proposed segmentation algorithm

Figure 9 shows the segmentation results of a "pears" image with objects having weak edges and smooth texture. Figure 9(a) shows the input image to our model. The figure 9 (b) shows the segmentation result that is obtained by the proposed watershed framework

The simulation analysis show that the proposed algorithm is superior to the existing supervised segmentation algorithms and in some cases on synthetic images it segments similar to the existing algorithms

VI. CONCLUSION

In this paper, we introduced a watershed based segmentation framework based on the combination of median filtering, sobel operation and soft thresholding process. The median filtering analysis offer a better smoothing means and thus reducing the impact of over segmentation on the images due to watershed algorithm. Soft thresholding that is carried based on the region's maximum value to obtain binary segments of various classes that boasted significantly the watershed algorithm performance. Simulation results and analysis proved that the proposed algorithm shows good performance in image segmentation without choosing the region of interest.

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