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Modified Watershed Segmentation with Denoising of Medical Images

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Abstract: De-noising and segmentation are fundamental steps in processing of images. They can be used as pre-processing and post-processing step. They are used to enhance the image quality. Various medical imaging that are used in these days are Magnetic Resonance Images (MRI), Ultrasound, X-Ray, CT Scan etc. Various types of noises affect the quality of images which may lead to unpredictable results. Various noises like speckle noise, Gaussian noise and Rician noise is present in ultrasound, MRI respectively. With the segmentation region required for analysis and diagnosis purpose is extracted. Various algorithm for segmentation like watershed, K-mean clustering, FCM, thresholding, region growing etc. exist. In this paper, we propose an improved watershed segmentation using de-noising filter. First of all, image will be de-noised with morphological opening-closing technique then watershed transform using linear correlation and convolution operations is applied to improve efficiency, accuracy and complexity of the algorithm. In this paper, watershed segmentation and various techniques which are used to improve the performance of watershed segmentation are discussed and comparative analysis is done.

Keywords: De-noising, Segmentation, Watershed, Region merging, RAG, Morphological Operations.

I. INTRODUCTION

Digital Image processing refers to processing of digital images by digital computers [1]. Now a day, in every field digital imaging is widely used. But image quality is major concern as various equipment errors, inefficiency and environmental factors degrade the quality of images by introducing noises in images. Noise is an unwanted signal present in the image but modifies the actual image content. But in most of areas like medical, satellite, pattern recognition etc. require images with zero tolerance to these noises. But it is not possibly to completely eliminate the noise but reduction can be done by applying various filters and then area which is needed for analysis purpose can be extracted from the image. Various filters that can be used for de-noising are median filter, wiener filter, hybrid filter, sobel operator etc. For segmentation watershed algorithm is discussed. But watershed algorithm suffers from over segmentation [5]. To remove over segmentation problem, various techniques are used i.e. marker controlled approach, region merging etc. The paper is organized as follows: first of all various de-noising techniques are discussed then Watershed algorithm combined with other approaches is discussed and after that Comparative analysis of various de-noising and segmentation techniques is given.

II. DE-NOISING OF IMAGES

De-noising refers to the process of eliminating unwanted signal from image. De-noising can be performed either in spatial domain or in frequency domain. Spatial domain refers to the image plane itself [1]. Image processing operations applied on image directly modify the pixels of image. Frequency domain refers to representation of image into various frequency bands. Various filters that are used for de-noising are mean filter, median filter, wiener filter, hybrid filter, modified hybrid filter.

A. Mean Filter

In this scheme, a 3*3, 5*5 or 7*7 kernel is used and scans over the whole image from left top corner to bottom right corner. Mean of all the pixels lying within window is calculated and then center pixel is replaced with calculated mean. Mean is calculated by adding all pixel values and divided by sum of kernel elements. Unpredictable results are produced at the boundary [1],[3]. To remove this problem either boundaries of image are appended with zero value or duplicate value as boundary value. But mean filter doesn't produce acceptable results as it is not necessary all elements within window are close to each other.

B. Median Filter

In this filter, same 3*3, 5*5 or 7*7 mask is used. Center pixel is replaced with the median of pixels lying in kernel window [1][3]. Median is calculated by sorting all the pixel values and then taking the middle element. It is efficient than mean filter but boundary is preserved in same way as in mean filter. Median filter is efficient for reducing speckle noise and salt & pepper noise.

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C. Wiener Filter

Wiener filtering is an inverse filtering technique which is used to recover blurred image and images corrupted with additive (Gaussian) noise [3]. It works in frequency domain. In this filter, it is assumed that signal and noise processes are second-order stationary. Wiener filter is slow as it is operated in frequency domain. But to increase the speed, inverse FFT of wiener filter is calculated to obtain the impulse response. Impulse response is truncated in spatial domain to generate convolution mask. Although performance of wiener filter is low in spatial domain as compared to frequency domain but speed is much higher. In wiener filtering, although MSE value is showing degrading results but visual representation of the image is better.

D. Hybrid Filter

In this filter, median and wiener filter are used. Noisy image is inputted to the median filter and output of median filter acts as input for wiener filter. This filter is used to reduce various noises like salt and pepper, Gaussian noise, impulse noise and blurring effect from images [4].

E. Modified Hybrid Median Filter

In this filter, combination of mean and median filter is used. The way of calculating mean and median is as follows:Suppose for n*n kernel, following matrix is produced to calculate the value.

|D	*	R	*	D|
|*	D	R	D	*|
|R	R	C	R	R|
|*	D	R	D	*|
|D	*	R	*	D|

First of all, find the mean of R (mean_r) values and mean of D (mean_d) values. Second, find the median (md) of pixels marked as D and central pixels C. Then calculate final median mm=median (mean_r, mean_d,md,C) and replace pixel $X_{i,j}$. This filter produces better results as compared to other filters [3].

F. De-noising Using Morphology

For morphological operations, two types of images are required: the original image on which processing need to be done and a structuring element of a specific shape that will act as a parameter to operation. Most commonly used morphological operations are dilation and erosion. Basically erosion shrinks the image means decreases the pixel values of the image and dilation expands the image means increases the pixel values of image. Based on erosion and dilation, morphological opening and closing operations are performed. Morphological opening is erosion followed by dilation operation. Morphological closing is defined as dilation operation followed by erosion. Using morphological operations for de-noising, the main concern is to select the appropriate structuring element. Structuring element should be large for removing noise [2].

III. SEGMENTATION OF IMAGES

A. Watershed Algorithm

Watershed segmentation is region-based segmentation whose idea comes from geography. Watershed algorithm is based on the image representation in three dimensions: two spatial coordinates and intensity. For topographic interpretation, three types of points are considered: A) points which belongs to regional minima. B) Points where if water drop is placed, it will fall with certainty to single minima. C) Points at which water is likely to fall to more than one minimum [1]. Imagine the landscape is submerged in a lake, with holes pierced in local minima. Watershed lines are divide lines of the domains of attraction of rain falling over the region. Watershed algorithm provides the complete division of the image [6]. It shows the connected regions with enclosed boundaries of single pixel wide. Main disadvantage of this algorithm is over-segmentation. Due to over-segmentation, regions are not clearly visible and it is sensible to noise. Various approaches are used to eliminate over segmentation like marker controlled approach, region merging etc.

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B. Approaches to Remove Over Segmentation

1) *Region Merging:* Region merging depends upon two criteria: a) region model, describing each region with a set of features. b) Dis-similarity measure, difference in the intensity values of two regions or dis-similarity between pixels along the boundaries. Merging on the basis of intensity is done by Region Adjacency Graph (RAG). Merging on the basis of features is done by computing texture features of regions.

2) *Region Adjacency Graph (RAG):* In this, graph structures are considered for implementation. Different regions are represented by nodes. Adjacency between regions is represented by drawing an arc. Dual RAGs are also commonly used in which nodes represent boundaries and regions are represented by arcs separating the boundaries.

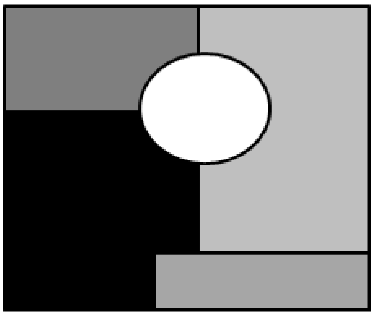

Fig.1. Segmented Image

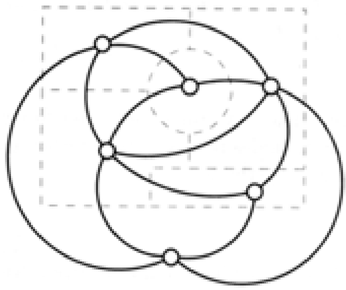

Fig. 2. Region Adjacency Graph

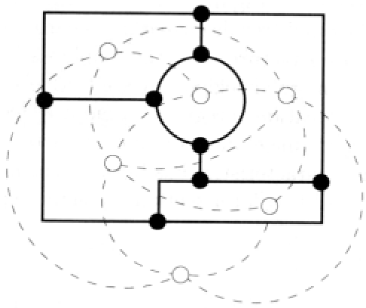

Fig. 3. Dual RAG

Figure 1 shows the image consisting of 5 regions. Figure 2 shows the region adjacency graph of image shown in figure 1. This has 5 nodes representing 5 different regions and 12 arcs showing adjacency between 5 regions. Figure 3 shows Dual RAG of the same image.

Algorithm of RAG based on boundary pixels:

1. Input an image and create its RAG.
2. For each region R_i
   a. Consider its neighbor region R_j.
   b. If R_i and R_j are similar, merge them to one region and update RAG.
3. Steps 2 and 3 will be repeated until no region will merge.

Similarity criteria: Two regions will be merged if boundary between them is weak [8].

Algorithm for region merging based on intensity values:

1. Calculate the size of each region say N_i.
2. Calculate the mean intensity of each region R_i and and denote this by:

$$M_i = \frac{1}{N_i} \sum_{(x,y)\in R_i} I(x,y) \qquad \text{......................(1)}$$

3. Define the criteria for two neighboring partitions I and j.
   a. Calculate the difference in the mean intensities between two partitions say i and j:

$$M_{ij} = |M_i - M_j| \qquad \text{........................(2)}$$

   b. Calculate the difference in the intensities between two partitions:

$$B_{ij} = \frac{1}{N_{ij}} \sum_{(x_i,y_i),(x_j,y_j)} |I(x_i,y_i) - I(x_j,y_j)| \qquad \text{...........................(3)}$$

4. Calculate Cij for similarity measurement in intensity values between two partitions:

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$$C_{ij} = \frac{1}{2}(M_{ij} + B_{ij}) \qquad \text{………………..(4)}$$

Choose the threshold value Tc. If Cij is less than Tc then regions will be merged otherwise not [7].

3) Marker-Controlled Approach

In this approach, foreground and background markers are extracted. For foreground markers, morphological operations, "opening by reconstruction and closing by reconstruction" is used. In this erosion followed by dilation operation is performed. For finding good foreground markers regional maxima is calculated. For marking the background pixels, thresholding operation is performed which results the binary image. Then watershed ridge lines are calculated. After that we find regional minima in certain locations to modify gradient magnitude image so that regional minima occur at foreground and background pixels [5].

4) Modified Marker-Controlled Approach

In this rather than using morphological operations, simple convolution and correlation operations are used for finding the foreground and background markers [5]. In convolution, two arrays of different sizes are multiplied to get the third array. One mask or kernel is used to calculate the convolution. The mask is scanned over the whole image and the output pixel value is weighted sum of input array within the mask where weights are the values assigned in mask to each pixel of the window. Mathematically convolution can be defined as:

$$convolution(f,k) = \sum_m \sum_n f(x-m, y-n)k(m,n) \qquad \text{……………..(5)}$$

Where *f* is the input image and k is the kernel of m*n size.

Convolution is equivalent to dilation in morphological operations

Correlation is almost similar to convolution, it is computed as a weighted sum of neighboring pixels. Weight matrix is known as correlation kernel which is 180 degree rotation of convolution kernel. Mathematically, it is defined as:

$$correlation(f,k) = \sum_m \sum_n f(x+m, y+n)k(m,n) \qquad \text{…………………….(6)}$$

Where *f* is input image and *k* is correlation kernel of mXn size.

Correlation is equivalent to erosion in morphological operations.

This modified marker-controlled algorithm is much faster than morphological based algorithm. Speed and accuracy of this algorithm is more as compared to old algorithm [5].

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IV. COMPARISON OF VARIOUS DE-NOISING FILTERS

TABLE 1 : COMPARISON OF VARIOUS DE-NOISING FILTERS

Filter	Working Principle	Advantages	Disadvantages
Mean Filter	Based on average value of pixels	Reduces Gaussian noise. Response time is fast	Results in distorted boundaries and edges
Median Filter	Based on the median value of pixels	Efficient for reducing salt & pepper noise, speckle noise. Boundaries and edges are preserved	Complex and time consuming as compared to mean filter.
Wiener Filter	Based on inverse filtering in frequency domain	Efficient for removing blurring effects from images	Due to working in frequency domain, its speed is slow. Doesn't provide good results for speckle noise.
Hybrid Filter	Combination of median and wiener filter	Removes speckle noise, impulse noise and blurring effects from images	Complex and time consuming
Modified hybrid median Filter	Combination of mean and median filter	Efficient for removing speckle, salt and pepper and Gaussian noise	Computation time is more as compared to simple median filter.
Morphology Based De-noising	Based on Morphological opening and closing Operations	Efficient and producing better results as compared to other filters	

V. COMPARISON OF VARIOUS SEGMENTATION ALGORITHMS

TABLE 2: COMPARISON OF VARIOUS SEGMENTATION ALGORITHMS

Segmentation Algorithm	Working Principle	Advantages	Disadvantages
Watershed Algorithm	Region-based algorithm. Basic idea comes from geography.	Produce complete division of the image	Over segmentation
Marker Controlled watershed Segmentation	Based on morphological operations.	Produce less number of segments as compared to watershed. Results obtained from this are very much efficient and clear.	Time complexity is more.
Modified Marker Controlled Watershed Segmentation	Based on convolution and correlation operations	Efficiently extract tumors and stones from images. faster as compared to morphological operations	
Watershed segmentation with texture based region merging.	Based on watershed and post processing is done on the basis of features of regions	After merging, number of partitions reduced to 80-90 percent	More computation time required.
Watershed segmentation and region merging with region adjacency graph	Based on watershed and post processing is done on segmentation map on the basis of intensity values	Number of partitions reduces gradually	Computation time required less as compared to texture based merging.
K-mean and watershed segmentation.[7]	Based on K-means, watershed, and region merging concept.	Number of merged segmentations regions are 85-95 approx. K-means reduces the problem of over segmentation also.	

VI. CONCLUSION AND FUTURE SCOPE

In this paper, we discussed about de-noising and segmentation techniques. As if segmentation alone is performed on the image, it does not produce acceptable results. So, to achieve better visualization of segmentation map, it should be pre-processed first to remove unwanted signals. It improves accuracy and helps in better interpretation. Final results obtained after segmentation depends upon the techniques applied for pre-processing of image, segmentation and post-processing technique.

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