A MODIFIED MARKER CONTROLLED WATERSHED ALGORITHM WITH LINEAR CONVOLUTION FOR MEDICAL IMAGE SEGMENTATION

Brijesh Shah[1], Jigar Modh[2] and Satish Shah[3]

[1] Associate Professor, C S. Patel Institute of Technology, CHARUSAT, Changa, Gujarat, India
[2] V.T.Patel Departments of Electronics and Communication Engineering,
[3] Professor, M. S. University, Baroda, Gujarat, India

ABSTRACT

Image segmentation plays an important role in the medical imaging. Image segmentation is the process to divide the image in the different region which has similar attributes. In this paper we proposed marker controlled watershed segmentation algorithm which works on gradient magnitude and use linear operation. The Linear convolution based image reconstruction algorithm used here is enables us to obtain better than general algorithm and morphological image reconstruction. This also reduces the overall time of algorithm than other marker controlled watershed algorithm. This method can be applied to noisy and degraded images. The use of markers can avoid the problem of over segmentation. The algorithm works on color as well as gray-scale images. The segmentations of X-ray image, MR image and also Mammographic images for breast cancer detection is shown in this paper. This algorithm can also be applied to high resolution satellite images.

KEYWORDS: SEGMENTATION, MARKER CONTROLLED WATERSHED ALGORITHM, MEDICAL IMAGES, LINEAR CONVOLUTION

1. INTRODUCTION

Watershed segmentation [1] is the most powerful segmentation technique in the area of digital image processing. Watershed transformation has widely adopted technique due to its many advantages, including simplicity, speed and complete division of image. Greyscale mathematical morphology of the watershed transform for the image segmentation is first proposed by Digabel and Lantuejoul (1977) [2] and later improved by Li et. al. (2003) [3].watershed transformation can be called as region based segmentation technique. The proposed algorithm presented here in this paper is more simplified than morphological based image reconstruction. The initiative description of this transform is quite simple: if we consider image as a topographic view, where the height of each point is directly related to its gray level. Now consider the rain is gradually falling on terrain then the watersheds are the lines separate the catchment basins that form. The watershed transform is computed on the gradient of original image. The catchment basin boundaries are located at high gradient point. The watershed transformation is widely used in many fields of image processing like medical image segmentation.

Most important drawback of watershed segmentation is the over segmentation. When the watershed transform is applied to the catchment basins from the gradient of the image, the result of the watershed contains a number of small regions. It makes a resulted segmentation hardly useful. So to use the markers in the image will reduce number of minima in the image. Thus marker controlled segmentation is used for watershed segmentation. [4]

In this paper we explain the marker controlled watershed segmentation for medical images like X-Ray and MR images and Mammographic images. The method overview is explained in section II. The proposed algorithm for this method is explained in section III. Section IV shows the Experimental results of the method and comparison with this algorithm with other algorithm. In this section we use X-Ray Image and MR image and Mammographic Images to see the results. In the end Section V dedicated to conclusion.

2. METHODOLOGY

In watershed segmentation there two basic approaches

Rain fall approach

In this approach local minima is found in all through the image and each local minima assigned an exclusive tag. An intangible water drop placed at each untagged pixel. And it assumes tag value.

Flooding approach

In flooding approach intangible pixel holes are pierced at each local minimum. The water enters in the holes and filling each catchment basin. If the basin is about to overflow, a dam is built on neighbouring ridge line to the height of high altitude ridge point. These dam borders can be called watershed ridge lines. [4]

2.1 Marker –controlled watershed transform

Applying watershed transform directly to the gradient image will results over segmentation. This is due to the irreverent minima, or noise patches or other irregularities. The concept of marker can be used to solve this over segmentation problem whose goal is to detect the presence of homogeneous regions from the image by the set of linear filtering operation. They spatially locate object and background ensuring to keep object interior as a whole [1].The marker controlled watershed algorithm proposed in this paper is robust and flexible method for image segmentation. Where the objects are closed contours and boundaries are ridges. The marker is the binary image used for watershed segmentation is either single marker points or larger marker region. Each marker is related to the specific watershed region. Thus number of the final number of watershed regions are equals to the number of markers. After segmentation the boundaries of watershed region are arranged to the desired ridges, so each object is separated from its neighbour.

2.2 Linear filtering Operation

Filtering operations reduces or increases the rate of change that occurs in the intensity transition within the image. Areas where there is sudden or rapid change in the intensity appear as hard edge in image, similarly where gradual changes produce soft edges. In the filtering it acts to detect or modify the rate of change at these edges. Filtering techniques are divided into two categories :Convolution filters (Linear filters) and Nonconvolution filters(Nonlinear filters)[14].here in this algorithm we most use convolution filters for image neighbourhoods by multiplying the value within neighbourhood by a matrix of filtering coefficient, however for creating markers we use morphological operation which is based non linear filters.

2.2.1 Convolution

Convolution is the most common to many image processing operators. Convolution is based on simple mathematical operation. Convolution is the way of multiplying two arrays of different sizes to produce a third array of numbers. In the Image processing Convolution is used to implement operators which are the Linear combination of certain input pixel value of image and produce the output pixel value [13]. Convolution is based on class of algorithm which is called spatial filters. This filters uses wide variety of masks or kernels, to calculate different results, depending on desired function.2-D convolution is most important to modern image processing .The basic idea is to scan a window of some finite size over an image. The output pixel value is the weighted sum of input pixels within the window where the weights are the values of the filter assigned to every pixel of the window. The window with its weights is called convolution mask or it can also be called kernels. The mathematical equation of the convolution for image is,

$$convolution(f,k)=\sum_{m}\sum_{n} f(x-m,y-n)k(m,n)$$

Where f is the input image and k is the kernel.

From the equation, it can be realized that convolution is similar to dilation in morphological operation with the use of structure element [12].

Steps of convolution in filtering process are,

1. Each pixel in the image neighborhood is multiplied by the contents of the corresponding element in the filtering kernel.
2. The results from the multiplication are summed and divided by the sum of the kernel.
3. The result is scaled and boosted , and used to replace the center pixel in the image neighborhood

2.2.2 Correlation

The correlation operation is closely related to convolution .similar to convolution operation, correlation computes the output pixels as a weighted sum of neighbouring pixels. The difference is that the matrix of weights in this case called correlation kernels, which is 180 degree rotation of convolution kernel. Correlation can be defined as,

$$correlation(f,k)=\sum_{m}\sum_{n} f(x+m,y+n)k(m,n)$$

Where f is the input image and k is the kernel,

Both correlation and convolution work as Erosion and Dilation in Morphological operation. In greyscale Images Convolution will increase the brightness of object by taking the neighbourhood maximum when passing with filter, as correlation will reduce the brightness of object by taking the neighbourhood minimum passing with filter.

3. Marker controlled watershed algorithm

In this paper marker controlled watershed algorithm is used which is simple algorithm to create foreground and background markers using linear filtering based image reconstruction. Here Image is converted in to the gradient images so that it represents the edge strength at each pixel [9, 10]. After that we use the correlation followed by convolution of image to traced foreground object. For finding the image convolution we define a circular average filter as mask or kernel. Calculating the extended regional maxima of these reconstructed images is done to get the smooth edge of foreground objects which is better than only regional maxima finding in image. Then we superimpose these markers to the original image. The background markers are created by calculating the Euclidian distance of binary version of above superimposed image. Now the gradient image is modified by the Linear filtering based reconstruction with foreground and background markers. Finally applying watershed transform on it will gives final segmented images of desired objects. The proposed algorithm can be seen in figure 1.

0

Figure 1 Algorithm

4. Experimental Results

Marker controlled watershed algorithm is very fast and advanced technique in image segmentation process. It converts the image in the gradient magnitude. Then Linear filtering operation is applying on gradient image. In the area of Medical Image Segmentation, marker controlled watershed algorithm performs well. It gives better result on X-ray, MR, and Mammographic images. In fig 2 we can see the original medical images. The fig 2.1 is an X-ray Image, in which we can see the stone in the kidney. Fig. 2.2 and 2.3 are MR images, which shows tumour in brain, and fig. 2.4 is the mammographic image, which shows tumour in breast. Fig 3 shows the gradient magnitude of original images.fig 4 is the visualization of the foreground marker, background marker and object boundaries applied on the original image, which was implemented by linear filtering. Finally fig. 5 is final watershed outputs of the original images, where objects like stone in the kidney and tumour in the brain and breast can be extracted from the original images. These results are better than the marker controlled watershed algorithm implemented with the morphological operation, which are shown in fig 6.From fig 6 it is compared that using morphological operation based algorithm, it fails to detect tumour in brain and breast. However it finds stone in kidney but it is more sensitive to other object in image also. Morphological operation is based on dilation, erosion, image opening and closing with reconstruction [5-8]. The modified marker controlled watershed algorithm with liner convolution and correlation is faster than morphological based algorithm. This comparison is shown in table 2, in which average CPU time of both the algorithm are compared .The speed and so that accuracy of new algorithm is higher than old algorithm. Table 1 shows the different CPU time of convolution based algorithm.

Figure 2.1 X-Ray Figure 2.2 MRI-1 Figure 2.3 MRI-2 Figure 2.4 Mammograph

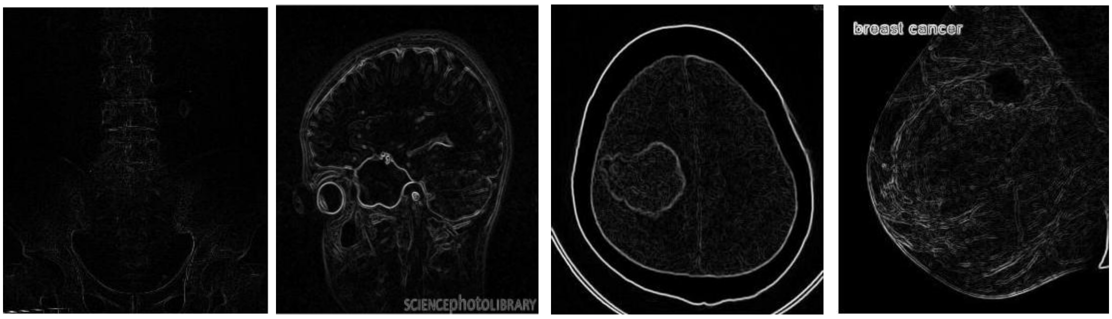

Figure 3 Gradient Magnitudes of Original Images

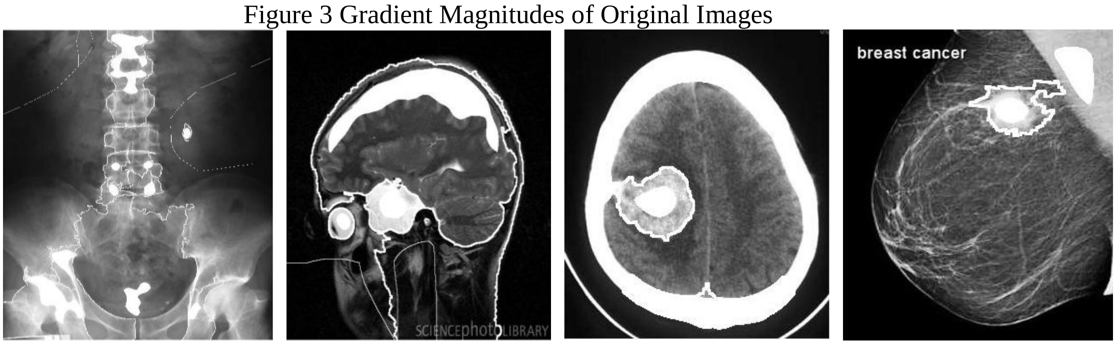

Figure 4 Markers and Objects Applied on Original Images

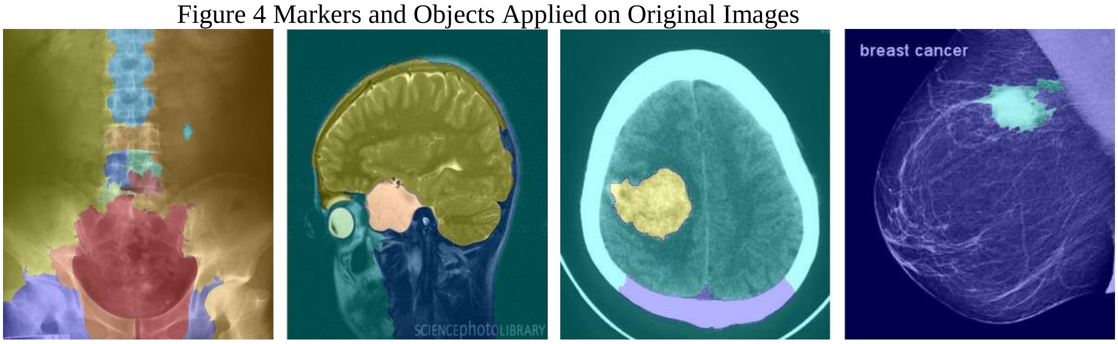

Figure 5 Final Watershed Output

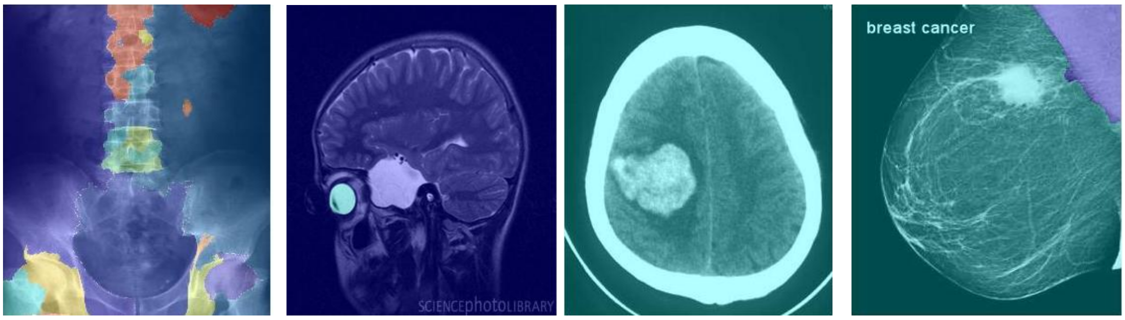

Figure 6 Comparison with Morphplogical based Watershed Algorithm

Image Type	Image Size	CPU Time-1 (sec.)	CPU Time-2 (sec.)	CPU Time-3 (sec.)	CPU Time-4 (sec.)	Average CPU Time (sec.)
X-ray	1536×2048	19.232	19.462	19.243	19.013	19.237
MR Image-1	530×530	3.370	3.463	3.510	3.426	3.442
MR Image-2	300×319	2.520	2.450	2.440	2.372	2.445
Mammographic Image	272×342	2.589	2.432	2.501	2.697	2.554

Table 1

Image Type	Image Size	Average CPU Time With Morphological Operation based Algorithm (Sec.)	Average CPU Time With Linear Convolution based Algorithm (Sec.)	Accuracy (%)
X-ray	1536×2048	23.199	19.237	17.07 %
MR Image-1	530×530	4.052	3.442	15.05 %
MR Image-2	300×319	3.041	2.445	19.60 %
Mammographic Image	272×342	3.110	2.554	17.88 %

Table 2

5. Conclusion And Future Work

The study shows that proposed Watershed algorithm by foreground marker is able to segment real medical images which containing several irregularities. The formulation is based on markers and simple convolution and correlation, which easily allows a regularization of the watershed, and is a flexible approach to the further optimization parameters. Implementing marker controlled watershed algorithm with morphology will increase computational cost and time consumption, because of several operations. Detection of object in medical images is also better in linear algorithm than morphological operation .So linear operation based marker controlled watershed algorithm is superior than morphology based algorithm. This algorithm can be merged with some advanced techniques like wavelet transform or it can be modify with some standard algorithm like fuzzy-c or k-means segmentation to improve the high resolution images specially in case of satellite images.

REFERENCES

[1] S. Beucher and F. Meyer, "The morphological approach to segmentation: The watershed transform," in *Mathematical Morphology in Image Processing*, E. R. Dougherty, Ed. New York: Marcel Dekker, 1993, vol. 12, pp. 433–481.

[2] Digabel, H., & Lantuejoul, C. (1977). Iterative algorithms. In J.-L. Chermant (Ed.), *Actes du Second Symposium Europeen d'Analyse Quantitative des Microstructures en Sciences des Materiaux, Biologie et Medecine*, Caen, 4-7 October 1977, pp. 85-99. Stuttgart: Riederer Verlag.

[3] Li, H., Elmoataz, A., Fadili, J. & Ruan, S. (2003)." An improved image segmentation approach based on level set and mathematical morphology". In H. Lu & T.Zhang (Eds.), *Proceedings of the Third international Symposium on Multispectral Image Processing and Pattern Recognition*, volume 5286, pp. 851-854.

[4] J. L. Vincent, "Morphological grayscale reconstruction in image analysis: Applications and efficient algorithms," *IEEE Trans. Image Processing*, vol. 2, pp. 176–201, 1993.

[5] J. Serra, *Mathematical Morphology*, vol. 1, Academic Press, London, UK, 1982.

[6] J. Serra, *Image Analysis and Mathematical Morphology*, Academic Press, London, UK, 1982.

[7] C. R. Giardina and E. R. Dougherty, *Morphological Methods in Image and Signal Processing*, Prentice-Hall, Upper Saddle River, NJ, USA, 1988.

[8] R. C. Gonzalez and R. E.Woods, *Digital Image Processing*, Prentice-Hall, Upper Saddle River, NJ, USA, 2nd edition, 2002.

[9] L. Vincent and P. Soille, "Watersheds in digital spaces: an efficient algorithm based on immersion Simulations," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 13, no. 6, pp. 583–598, 1991.

[10] Gonzalez, R.C., R.E. Woods and S.L. Eddins, 2004.Digital Image Processing using MATLAB. 1st Edn, Pearson Education India, India, ISBN: 9788177588989, pp: 620.

[11] Imdad Rizvi, B K Mohan, ''Wavelet based Marker-Controlled Watershed Segmentation Technique for High Resolution Satellite Images''2nd International Conference and workshop on Emerging Trends in Technology (ICWET) 2011.

[12] B.Kisacanin,c.schonfeld,"A Fast threshold Linear Convolution Representation of Morphological Operations",IEEE Transactions on Image Processing, ,1994

[13] Mariusz Jankowski,"Erosion, dilation and related operators"8th international mathematica symposium, Avignon 2006.

[14] Steven W.Smith,'The Scientist and Engineer's Guide to Digital Signal Processing",chapter 4.