Global Contrast Enhancement for Effective Medical Image Segmentation

[1]Sonia Corraya and [2]Mohammad Shorif Uddin

Department of Computer Science & Engineering, Jahangirnagar University, Savar, Dhaka

Email: [1]fransin_130@yahoo.com, [2]shorifuddin@gmail.com

Abstract—Segmentation is a preliminary step to analyze medical images for computer-aided diagnosis and therapy. In this work a Global Contrast Enhancement (GCE) based technique is proposed to improve medical image segmentation for identifying tumors. At first medical image is pre-processed to reduce noise then multi-level histogram is generated and modified using GCE. Next, segmentation process is carried out for MRI and CT scan images. Segmentation results obtained by normal histogram, equalized histogram and GCE histogram are compared.

Keywords— Histogram Equalization and Modification, Global Contrast Enhancement, Medical Image Segmentation

Manuscript received on 15 August 2013 and accepted for publication on 29 October 2013.

1 Introduction

IMAGE segmentation is increasingly used in analyzing medical imaging data sets. In modern medical science, segmentation accuracy is very important for computer-aided diagnosis and therapy. It is a difficult as well as challenging task due to the complex nature of medical images. There exist various methodologies for medical image segmentation but due to missing features and accuracy of the results are not up to the mark [1], [2], [3], [4]. In this paper a GCE-Based segmentation technique is proposed to improve the accuracy level of medical image segmentation. In addition to identify tumor area from MRI and CT scan segmented images, the proposed technique is smart enough in extracting other features and edges from the segmented medical images as well.

Previously, Tarik Arici [9] proposed a Global Contrast Enhancement Technique of histogram modification. However, it has not been applied widely due to accuracy.

With a view to improve the present segmentation methodology of MRI and CT scan images [8] we have successfully applied the GCE-Based technique and achieved better segmentation accuracy. Our aim is to achieve more accurate segmented result which is the key point for overall diagnosis. To confirm the effectiveness of the proposed method, an experiment is performed using 50 real MRI images and 50 real CT scan images with and without tumors. Images are collected from medical image database of internet.

The rest of the paper is organized as follows. Section 2 provides a description of the proposed technique. Evaluation process and concerns are presented in Section 3. Section 4 discusses the experimental results and analyzes the performance. Finally, conclusions are drawn in section 5.

2 Methodology

Image segmentation is the process of dividing an image into regions or objects. It is a basic step in image analysis. Segmentation accuracy determines the eventual success or failure of computerized analysis procedure [6], [11]. Magnetic Resonance Imaging (MRI) is an important diagnostic imaging technique utilized for early detection of abnormal changes in tissues and organs [9]. It possesses good contrast resolution for different tissues and is, thus, preferred over Computerized Tomography (CT) for brain study [6]. Therefore, the majority of research in medical image segmentation concerns MR images [6], [8], [10]. Since MR images are gray level image; the segmentation technique proposed in this paper is for gray-level images.

2.1 Histogram Equalization

Histogram equalization (HE) is an effective technique for contrast enhancement. However, HE without any modification usually results in excessive contrast enhancement, which in turn gives the processed image an unnatural look and creates visual artifacts [9]. As a result all details of the captured image are not revealed. HE enhances the contrast of images by transforming the values in an intensity image [5]. Mathematical expression for HE is given in equation (1).

$$x' = T(x) = \sum_{i=0}^{x} n_i . \frac{\text{max. intensity}}{N} \quad (1)$$

where n_i is the number of pixels at intensity i; N is the total number of pixels in the image. According to equation (1), the input pixel intensity, x is transformed to new intensity value, x′. The transform function, T(x) is the product of a cumulative histogram and a scale factor. The scale factor is needed to fit the new intensity value within the range of the intensity values, for example, 0 ~ 255.

2.2 Global Contrast Enhancement Based Histogram Modification

The level of contrast enhancement can be adjusted by introducing specifically designed penalty terms [9]; for obtaining more visually pleasing and informative image. In GCE-Based histogram modification technique minimum intensity of the image is the gray-level range for black stretching b and maximum intensity value is the gray-level range for white stretching w [9]. For each bin n of the input image histogram, the modified histogram is represented by equation (2).

$$\tilde{h} = \frac{h_i + \lambda u}{1+\lambda} = \left(\frac{1}{1+\lambda}\right)h_i + \left(\frac{\lambda}{1+\lambda}\right)u \text{ , } b<n<w \qquad (2)$$

Where $\tilde{h}$ is the modified histogram, hi is the input histogram, λ is for achieving various level of contrast enhancement. By changing λ, the level of enhancement can be adjusted, u is the minimum between average intensity frequency and the most frequently occurred intensity value in the histogram.

Otherwise, the histogram is modified using the following equation (3).

$$\tilde{h} = ((1+\lambda)I + \alpha I^B)^{-1}(h_i + \lambda u) \qquad (3)$$

Where I^B is a diagonal matrix. $I^B(i,i)$ =1 for $i \in \{[0,b] \cup [w,255]\}$, and the remaining diagonal elements are zero. α is for the more natural look of the black and white in the image, which varies for different kind of images.

2.3 Global Contrast Enhancement (GCE) Based Segmentation Technique

Block diagram of the GCE-Based image segmentation process is presented in Figure 1. At first the input image is converted to grayscale and then resized to (256 × 256). The whole process is divided into five distinct steps:

a) **Pre-processing:** At the pre-processing step, the Median filter is used to remove noise from the input gray scale image [8]. The moving window for the median filter is (3 × 3).

b) **Edge Detection:** Sobel edge detector is used. The output image of the edge detection process is used to increase the intensity values of the edge pixels in the original image [8], [7].

c) **Histogram Construction:** Histogram of the resultant image, from step b, is constructed using equation (1).

d) **GCE Based Histogram Modification**: The generated histogram is modified using the GCE-Based histogram modification technique [9].

e) **Segmentation**: Output results are generated by multilevel segmentation (Multimodal Gray Scale Image Histogram Thresholding) technique.

3 Evaluation Process and Concerns

The proposed method is implemented and tested in MATLAB R2009a environment by using a computer of Pentium 4, 2.8 GHz with 1 GB RAM in Windows XP platform. The efficiency of the proposed method is evaluated by both visual and numerical inspection.

3.1 Visual inspection

For visual inspection all resultant segmented MRI and CT scan images are analyzed by expert (radiologist) to find the most accurate result. The resultant segmented images using normal histogram Hi, equalized HE and GCE-Based modified histogram methods are evaluated using a scale of 1 to 10. Score 10 is given when the segmentation is perfect while the score 1 is given when the segmentation accuracy is unacceptable [10].

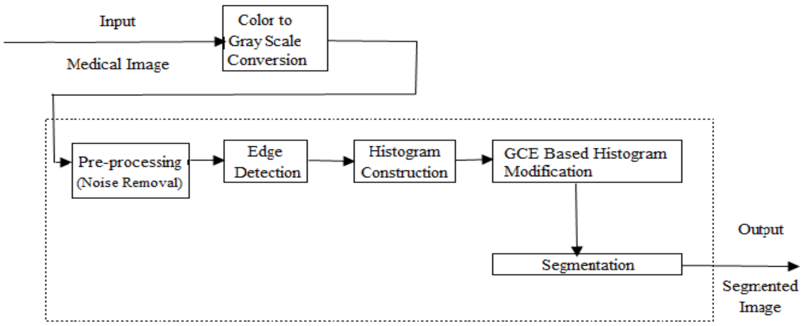


Figure 1: Block diagram of GCE-Based Segmentation Process

3.2 Numerical Inspection Using the Hausdorff Distance

In pattern recognition and computer vision field the central problem is determining the extent to which a shape resembles another shape [11]. For this work we have considered the Hausdorff distance in determining the extent to which a point of an 'image' resembles a point of a 'model' [11].

The Hausdorff distance

For a set A = *{a1,….,ap}* and B = *{b1,….,bp}* the Hausdorff distance between A and B is defined by equation (4) and equation (5).

$$H(A,B) = \max(h(A,B), h(B,A)) \quad (4)$$

With the directed Hausdorff distance defined as

$$\vec{h}(A,B) = \max_{a\in A}\min_{b\in B} \| a-b \| \quad (5)$$

Equation (4) is for scalar and equatin (5) for vector representations.

4 Experimental Results and discussions

Figure 2 and Figure 3 show the comparative segmentation results. The former showing for MRI and the latter for CT scan images. Both Figure 2 and Figure 3 show that tumor area is detected in segmented MRI and CT scan medical images more clearly and correctly by using GCE-Based segmentation technique. In quantitative analysis the segmented images are compared using Hausdorff distance [12]. Ground truth images are prepared from original MRI and CT scan images by manual segmentation in the presence of a radiologist. After that Hausdorff Distance is calculated for the ground truth and segmented images [11]. The result analysis is concluded with the use of three types of histograms (Hi, HE and GCE). TABLE 1 and TABLE 2 summarize the average results of visual and numerical inspections.

Visual inspection results in TABLE 1 show that, the highest degree of accuracy of segmentation (for MRI 8.34 and for CT scan Image 8.18) is achieved by GCE-Based technique. Numerical Inspection results in TABLE 2 show that, by using GCE-Based segmentation technique, Hauadorff Distance is decreased by 8.68% for MRI and 7.14% for CT scan medical image. This means closely ground truth images are generated by GCE-Based method rather than the histogram equalization technique.

The proposed method can be applied not only for medical imaging, but can also be applied to any image processing problems in which segmentation is required. Here are some scopes or good challenges for future work. The proposed methodology can be further extended to adapt various filters at the last stage of the process after the segmentation. For X-ray and Ultrasound medical images the proposed method can be further evaluated. Rather than the use of sobel edge detector at the edge detection step [7], other edge detector operators like Canny, Prewitt, Roberts, Laplacian etc. can be investigated.

At the pre-processing step, instead of median filter, other noise removing techniques can be adopted as well for specific type of noise (i.e. despeckle noise) in input images.

Figure 2 and Figure 3 show the comparative segmentation results. The former showing for MRI and the latter for CT scan images. Both Figure 2 and Figure 3 show that tumor area is detected in segmented MRI and CT scan medical images more clearly and correctly by using GCE-Based segmentation technique. In quantitative analysis the segmented images are compared using Hausdorff distance [12]. Ground truth images are prepared from original MRI and CT scan images by manual segmentation in the presence of a radiologist. After that Hausdorff Distance is calculated for the ground truth and segmented images [11]. The result analysis is concluded with the use of three types of histograms (Hi, HE and GCE). TABLE 1 and TABLE 2 summarize the average results of visual and numerical inspections.

Visual inspection results in TABLE 1 show that, the highest degree of accuracy of segmentation (for MRI 8.34 and for CT scan Image 8.18) is achieved by GCE-Based technique. Numerical Inspection results in TABLE 2 show that, by using GCE-Based segmentation technique, Hauadorff Distance is decreased by 8.68% for MRI and 7.14% for CT scan medical image. This means closely ground truth images are generated by GCE-Based method rather than the histogram equalization technique.

The proposed method can be applied not only for medical imaging, but can also be applied to any image processing problems in which segmentation is required. Here are some scopes or good challenges for future work. The proposed methodology can be further extended to adapt various filters at the last stage of the process after the segmentation. For X-ray and Ultrasound medical images the proposed method can be further evaluated. Rather than the use of sobel edge detector at the edge detection step [7], other edge detector operators like Canny, Prewitt, Roberts, Laplacian etc. can be investigated.

At the pre-processing step, instead of median filter, other noise removing techniques can be adopted as well for specific type of noise (i.e. despeckle noise) in input images.

TABLE 1

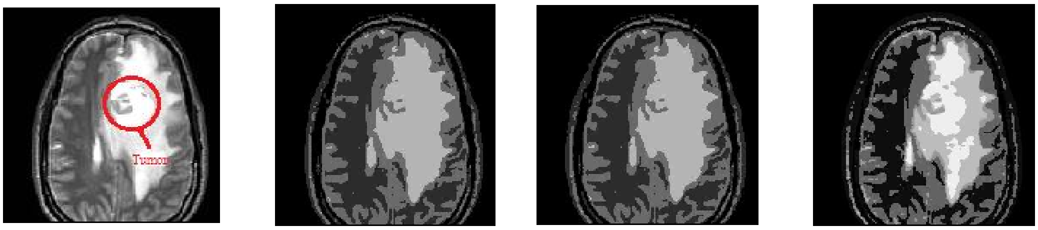
VISUAL INSPECTION RESULTS FOR MRI AND CT SCAN IMAGES

Image Histogram used in Medical Image Segmentation	Degree of Accuracy of the Segmentation (out of 10)	
	MRI Medical Image	CT Scan Medical Image
Normal Histogram (Hi)	5.5	3.96
Equalized Histogram (HE)	5.6	3.89
GCE-Based Modified Histogram	8.34	8.18

TABLE 2

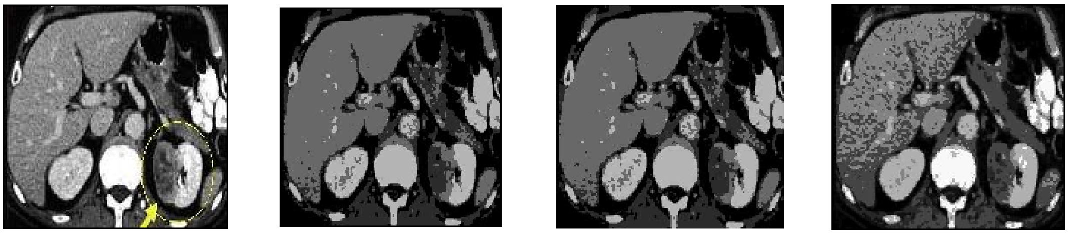
NUMERICAL INSPECTION RESULTS USING HAUSDORFF DISTANCE FOR MRI AND CT SCAN IMAGES

Image Histogram used in Medical Image Segmentation	Hausdorff Distance Decreased By (%)	
	MRI Medical Image	CT Scan Medical Image
Equalized Histogram (HE)	0	0
GCE-Based Modified Histogram	8.68	7.14



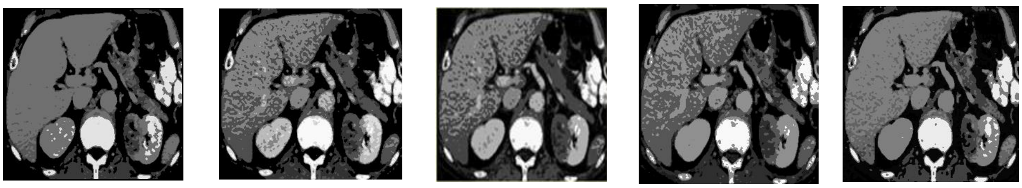
(a) (b) (c) (d)

Figure 2: Comparison results of MRI medical image segmentation (a) tumor in original brain MRI; resultant segmented image using (b) normal histogram method (c) histogram equalization method and (d) GCE-Based histogram modification method



(a) (b) (c) (d)

Figure 3: Comparison results of CT scan medical image segmentation (a) tumor in original kidney CT scan (Renal tumor); resultant segment image using (b) normal histogram method (c) histogram equalization method and (d) GCE-Based histogram modification method



(a) α=3 (b) α=4 (c) α=5 (d) α=6 (e) α=7

Figure 4 : Effects of different level of enhancement value α on segmentation results of Kidney Tumor CT scan image using GCE-Based Segmentation Method (a) α=3 (b) α=4 (c) α=5 (d) α=6 (e) α=7

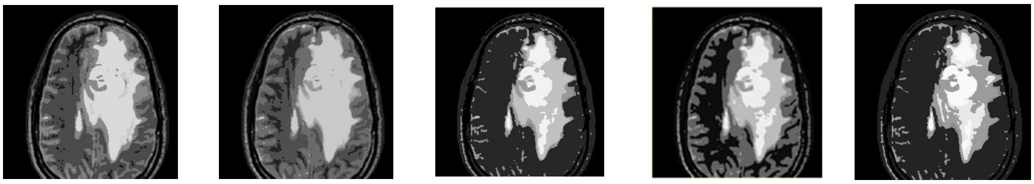


Fig: (a) α=3 Fig: (b) α=4 Fig: (c) α=5 Fig: (d) α=**6** Fig: (e) α=7

Figure 5: Effects of different level of enhancement value α on segmentation results of Brain Tumor MRI using GCE-Based Segmentation Method (a) α=3 (b) α=4 (c) α=5 (d) α=6 (e) α=7

Figure 4 and Figure 5 show the performance under different values of α (=3, 4, 5, 6, 7) for MRI and CT scan images respectively. It is difficult to set the level of enhancement α automatically. In this paper we have taken the opinion of expert (radiologist) to set the value of α. According to expert's visual evaluation the value of α is set to 5 for MRI segmentation and for CT scan image segmentation its set to 6. Adaptive setting of αis very important which we will investigate in our next work. The system works for still images only, not able to segment real time images.

5. Conclusion

In this paper an effective GCE based segmentation method is proposed. The method generates segmented medical image based on GCE based histogram modification. Experimental results show that the method is quite successful in identifying tumors and other features from resultant segmented image. We Hope this technique will help in increasing the accuracy of computer guided surgery, therapy and other medical data set analysis as well. We have not tested our method for X-ray and ultrasound medical image. In the future, we would like to investigate on X-ray and ultrasound images.

References

[1] Thrasyvoulos N. P., "An Adaptive Clustering Algorithm for Image Segmentation," IEEE Transaction on Signal Processing, vol. 40, no. 4,pp. 901-914, 1992. Tou J. T. and Gonzalez R. C., Pattern Recognition Principles, Addison Wesley, USA, pp. 75-97, 1974

[2] Vincent L. and Soille P. "Watershed in Digital Space: An Efficient Algorithm Based on Immersion Simulations," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 13, no. 6, pp. 583-593, 1991.

[3] Yan M. X. H. and Karp J. S., "Segmentation of 3D Brain MR Using an Adaptive K-means Clustering Algorithm," in the Proceedings of the 4th IEEE Conference on Nuclear Science Symposium and Medical Imaging, San Francisco, USA, vol.4., pp. 1529-1533, 1995.

[4] Yu Y. and Wang J., "Image Segmentation Based on Region Growing and Edge Detection," in Proceedings of the 6th IEEE International Conference on Systems, Man and Cybernetics,Tokyo, vol.6., pp. 798-803, 1999.

[5] Linda G. Shapiro and George C. Stockman, "Computer Vision", pp 279-325, New Jersey, Prentice-Hall (2001)

[6] Pham, Dzung L.; Xu, Chenyang; Prince, Jerry L. (2000). "Current Methods in Medical Image Segmentation", Annual Review of Biomedical Engineering 2: 315–337

[7] Chowdhury M. I. and Robinson J. A., "Improving Image Segmentation Using Edge Information," in Proceedings of the 1st IEEE Conference on Electrical and Computer Engineering, Halifax,Canada, vol.1, pp. 312-316, 2000.

[8] T.K. Ganga, Dr. V. Karthikeyani, "Medical Image Segmentation Using Histogram Equalization Technique With Inverse Radon transform", International Journal of Engineering Science and Tech-

nology (IJEST), Vol. 3 No. 5 May 2011
[9] Tarik Arici, Salih Dikbas, "A Histogram Modification Framework and Its Application for Image Contrast Enhancement", IEEE Transactions on Image Processing, vol.18, no.9, September 2009
[10] G. M. N. R. Gajanayake, R. D. Yapa and B. Hewawithana, "Comparison of Standard Image Segmentation Methods for Segmentation of Brain Tumors from 2D MR Images", 4th International Conference on Industrial and Information Systems, ICIIS 2009, IEEE, University of Peradeniya, SriLanka, pp.301-305.
[11] Krit Somkantha, Nipon Theera-Umpon, "Boundary Detection in Medical Images Using Edge Following Algorithm Based on Intensity Gradient and Texture Gradient Features", IEEE Transactions on Biomedical Engineering, vol.58, no.3, March 2011
[12] X.W.Zhang, J.Q.Song, M.R.Lyu, and S.J.Cai," Extraction of karyocytes and their components from microscopic bone marrow images based on regional color features", Pattern recognition, vol.37, no.2, pp.351-361, 2004

Sonia Corraya completed her B.Sc. (Honors) and MS in Computer Science and Engineering from Jahangirnagar University, Savar, Dhaka in 2009 and 2012 respectively. She secured the highest grade in the MS final examination 2009 at Jahangirnagar University for the first time in the department. She is now working as a Specialist - Business Intelligence / Data Warehouse and Customer Life Cycle Management Systems at a multinational company. Her research interests are on, Computer Vision and Pattern Recognition, Data Mining, Database management System, Artificial Intelligence, Bioinformatics, Image Processing and Machine Learning.

Mohammad Shorif Uddin received his PhD in Information Science from Kyoto Institute of Technology, Japan, Masters of Education in Technology Education from Shiga University, Japan and Bachelor of Science in Electrical and Electronic Engineering from Bangladesh University of Engineering and Technology (BUET). He joined the Department of Computer Science and Engineering, Jahangirnagar University, Dhaka in 1992 and currently serves as a Professor of this department. He began his teaching career in 1991 as a Lecturer of the Department of Electrical and Electronic Engineering, Chittagong University of Engineering and Technology (CUET). He undertook postdoctoral research at Bioinformatics Institute, A-STAR, Singapore, Toyota Technological Institute, Japan and Kyoto Institute of Technology, Japan. His research is motivated by applications in the fields of computer vision, pattern recognition, blind navigation, bio-imaging, medical diagnosis and disaster prevention. He has published a remarkable number of papers in peer-reviewed international journals and conference proceedings. He holds two patents for his scientific inventions. He received the Best Paper Award in ICIEV2013 Dhaka, Bangladesh and Best Presenter Award from the International Conference on Computer Vision and Graphics in ICCVG 2004, Warsaw, Poland. He is the co-author of two books. He is also a member of IEEE, SPIE, IEB and a senior member of IACSIT