Segmentation of CT Brain Stroke Image using Marker Controlled Watershed

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Abstract

In this paper, an algorithm is proposed to detect and segment ischemic stroke from CT brain images. Firstly, our proposed method starts by a preprocessing step contains skull bone striping and text removal from CT images, then the images are enhanced using median filter and histogram equalization. Next the watershed segmentation and Marker Controlled watershed methods is applied to detect the ischemic stroke. The experimental results show that Marker controlled watershed is better than the watershed due to over segmentation caused by the noise of the CT image. The over segmentation problem was resolved and succeeded to detect and segment the infarcted regions in the CT Ischemic stroke image that will help the non-radiologists identify the stroke visually.

Keywords—Stroke, Ischemic, CT, Brain, Watershed, Segmentation, Minima, Maxima

I. Introduction

"Brain is Time and Time is Brain" [1] which reflects and highlights the importance of time whenever brain damage occur due to a stroke incidence which is a cutoff of blood flow to a brain area. Annually, 15 million people worldwide suffer a stroke [2]. Of these, 5 million die and another 5 million left permanently disabled, placing a burden on family and community [3]. Death of stroke patient rate in Lebanon is 1.952 or 10.43% of total death number. Death relative to age is 39.86 for every 100,000 citizen. Lebanon rated as 138 worldwide [4]. Around 87% of stroke cases are classified as ischemic which is the blockage of a brain artery by a blood clot. In this paper, a method will be presented to assist the emergency physician and non-radiology doctors to identify and segment ischemic stroke and infarcted region of the brain in order to save time, especially identification and segmentation of infarcted region is very challenging from non-enhanced CT image which is the first imaging modality in emergency room in order to diagnose stroke patient and of course less scanning time than MRI. The main criteria that the neuro radiologist looks for in the stroke CT image is the loss of the differentiation between cortical grey and subcortical white matter and Hypo dense changes that is the most common sign of early ischemia [5] [6]. The method is applied on three ischemic stroke patients and one normal patient from Lebanon and Saudi Arabia respectively.

II. Literature Review

Roman Peter et al [7] presented a method for detection of ischemic stroke. In non-contrast CT (ncCT), by comparing right and left hemispheres of the brain and looking for the differences between ischemic changes relying on symmetry analysis. Amina Fatima Zahra Yahiaoui et al [8] proposed an algorithm based on Laplacian Pyramid (LP) using the Fuzzy C Means for classification. Alyaa Hussein Ali et al [9] used as segmentation a Thresholding method and Region Growing and getting the statistical features. Yeu-Sheng Tyan et al [10] detected ischemic stroke through an unsupervised feature perception enhancement by an unsupervised region growing algorithm and Canny edge detection technologies algorithm. Tomasz Hachaj et al [11] analyzed computed tomography perfusion (CTP) maps to increase its efficiency in detection and classification of abnormal perfusion by using a new neural network algorithm with multi-layer perceptron. Varsha Gupta et al [12] presented segmentation algorithm for cerebrospinal fluid (CSF), white matter (WM), and gray matter (GM) on unenhanced computed tomographic (CT) images using adaptive thresholding, connectivity, domain knowledge and uses the shape of CT histogram.

III-Methodology

The method used is demonstrated in Figure 1, which will be consisting of the following steps:

1- Preprocessing
2- Image enhancement.
3- Image segmentation.

1-Preprocessing Step

A- Grey Scale Image:

CT image whether it is in Dicom or JPEG format should be changed to gray scale for further processing. The CT Dicom image is a 16-bit image. The image possesses 4-bit for textual information and 12-bit for display [13]. The CT number (attenuation number) of pixel (i, j) is in the Hounsfield unit (HU) which can be converted to the DICOM grey level by the following equation:

$$\mathrm{HU}\ (i,j) = m \times Y(i,j) + a \tag{1}$$

(Y) is DICOM grey level; (m) is rescale slope; (a) is rescale intercept.

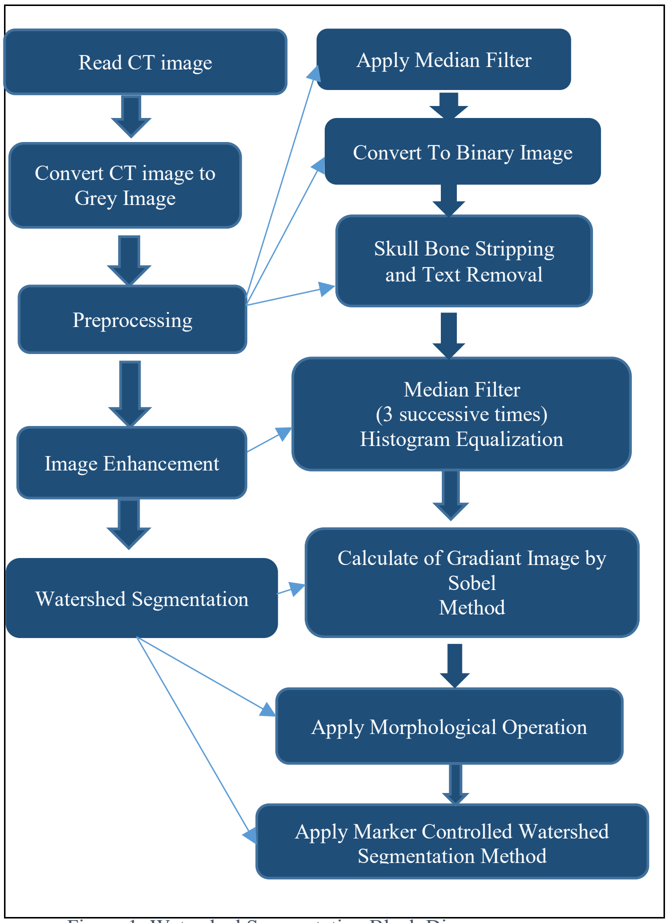


Figure 1: Watershed Segmentation Block Diagram

Those parameters (m) and (a) can be found in the textual information in the DICOM image. Usually the dynamic range of CT image in the HU is from -1000HU to 1000HU. In order to view the image is to convert it into visible 256-greyscale range (linear intensity windowing or window setting). The range of the HU is called the window width (W) and the center of the range is called the window center (C). The window setting is achieved by the below formula (2). The HU range outside the window width will be set to level 0 and level 255.

$$\mathrm{F(i,j)} = (\mathrm{HU(i,j)} - (\mathrm{C} - \mathrm{W}/2))/\mathrm{W} \times 255 \quad (2)$$

B- Filtering

The smoothing Non Linear Filters are many like Min Filter, Max Filter, Mid-Point Filter and Median Filter. We used in our method three successive Median filters as a filtering approach to remove the noises that will cause a lot of problems if not resolved and affect our results. It performs better than min, max and mid-point filters by removing many types of noises and less blurring than small sized linear filters [19].

C-Image Binarization

After getting the gray scale image, it is changed to Binary Image in order to remove the un-useful data (Patient demographics) and skull bone stripping.

D-Text Removal and Bone Stripping

A Thresholding method is used to remove the skull bone by global thresholding by setting the bone region to zero value and the brain tissue to one value. The average CT intensity is 1000HU for bones so any threshold less than 200 HU will remove the bone [14]. Morphological operations will be performed to the image so that the eroded binary image is used as a mask for the gray image to get the final skull bone stripped image.

2-Image Enhancement:

Image enhancement is the process that emphasizes, sharpens and feature smoothing for further analysis and processing [15]. Histogram equalization is used to enhance our image. Histogram Equalization reset the grey values into new values by a nonlinearly transform function acquired from the normalized cumulative distribution of the image [16]. The grey level X of an image is in the range of [0, 255]. The probability density function (PDF) of level Xk is obtained by the following [17]:

$$\mathrm{p(X\_k\,)} = \mathrm{n\_k/n} \quad (3)$$

nk is the number of pixels at level Xk; n is the total number of pixels in the image. The cumulative distribution function (CDF) of level Xk is obtained from the PDF by the following formula:

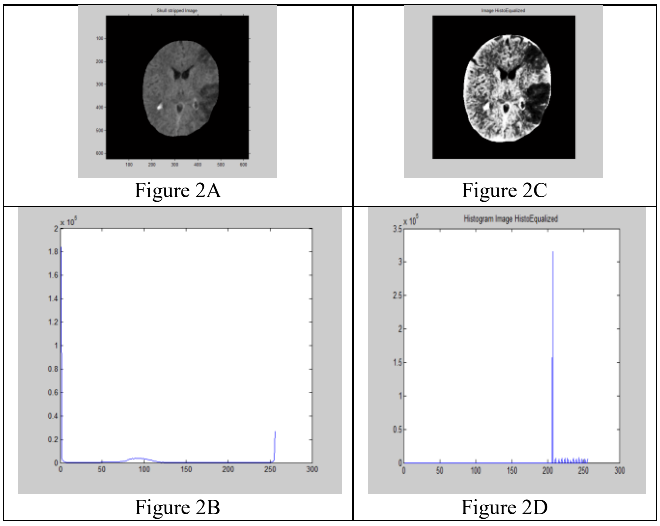
$$c(X_k) = \sum_{b=0}^{k} p(X_k) \quad (4)$$

The transform function (TF) is:

$$\mathrm{TF} = (\mathrm{X\,max} - \mathrm{X\,min}\,)\mathrm{C(X\,k\,)} + \mathrm{X\,min} \quad (5)$$

X max and X min are the maximum and minimum grey level in the output image. The transform function is the normalized CDF when the input image is normalized into grey level of [0, 1]. The Histogram Equalization stretches the levels with high probability more than the levels with low probability.

Figure 2: Fig 2A is Original image after preprocessing; Figure 2B is the Histogram; Figure 2C is image after histogram equalization; Figure 2D is histogram of image after histogram equalization performed [18].



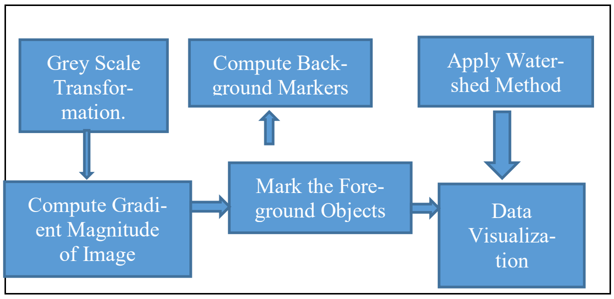
3-Segmentation

Image Segmentation is defined by dividing the image into set of regions. Each region composed of a set of border pixels grouped into forms like a line segments and circular arc ellipse or polygon segments in images. When the regions of interest do not cover the whole image, image is segmented into foreground regions of interest and background regions that should be ignored [20]. Therefore, the aim of image segmentation is discriminating different objects and background in the image. Usually differentiated by Color, Texture or Motion [21]. In our method, we used the Watershed for the segmentation based on color and texture variations.

3.1 Watershed:

The watershed has been researched since the 19th century (Maxwell, Jordan . . .) especially in topography purposes [22].

Figure 3: Marker controlled watershed block diagram



Watershed segmentation is considered as a method of region-based segmentation that has its origins in mathematical morphology. In watershed segmentation, the 2-D, grey-scale image is considered as a topological surface or 'landscape' in which (x, y) coordinates is located and having a height at that location corresponds to the image intensity (Grey Value) [21]. Watershed is similar to imagining that when the water level reaches the height of the highest peak, the construction process stops. The dams are the watersheds, which divides the landscape into distinct regions containing a catchment basin. In watershed segmentation, the Catchment Basin represents the object we want to segment. First, computation of the gradient image should be done because the gradient magnitude is high at the object edges and low otherwise. If watershed segmentation is applied directly, an over segmentation of the image will be resulting due to the many catchment basins corresponding to a minimum of the gradient, which are produced by small variation due to noise in grey levels. The main approaches to solve the over-segmentation either by minimizing the number of minima or by filtering through merging the regions according to similarity after applying watershed [24].

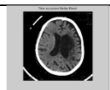
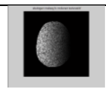
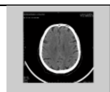
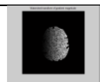
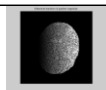
3.2 Marker Controlled Watershed Method

The method of Marker controlled watershed is used to overcome the over-segmentation caused by noise. The block diagram of Marker controlled watershed is shown in Figure 3. After converting the image into Grey scale, the gradiant image is computed by using Sobel filter. The gradient is high at the borders of the objects and low (mostly) inside the objects.
The Foreground Objects is marked. These are connected blobs of pixels within each of the objects. A variety of procedures could be applied here to find the foreground markers, which must be connected blobs of pixels inside each of the foreground objects. In this method, morphological techniques is used and called "opening-by-reconstruction" and "closing-by-reconstruction" to "clean" up the image. These operations will create flat maxima inside each object. Opening is an erosion followed by a dilation, while opening-by-reconstruction is an erosion followed by a morphological reconstruction [25]. By this, the dark spots and stem marks are removed. Morphological reconstruction is a useful method for extracting information and data about shapes in an image, like extracting marked objects. Now the regional maxima of the (opened-closed by reconstruction) image is calculated to obtain good foreground markers. Now marking the background is necessary. In the cleaned-up image, the dark pixels belong to the background, so you could start with a thresholding operation. Compute the watershed transform of the modified segmentation function. The watershed transform of the distance transform of binary image is computed and then looking for the watershed ridgelines of the result. Now the Watershed Transform of the Segmentation Function is computed. The regional minima is imposed only in certain desired locations and modify the gradient magnitude image so that its only regional minima occur at foreground and background marker pixels.

4-Experimental Results

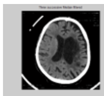
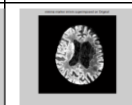
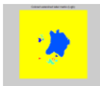
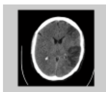
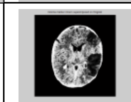
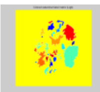
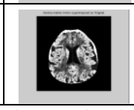
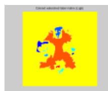
After applying the Marker controlled watershed segmentation and performing the required filtering and morphological operations, the results obtained are quiet satisfying as shown in Table 1, 2, 3 and 4. Table 1 contains the original image and over-segmentation of watershed for four patients. Table 2 contains the CT images after assigning the markers on the original mage and applying the marker controlled watershed and clear segmentation of the CT image. In addition, the colored marker controlled watershed (colored matrix of watershed) is obtained where the infarcted areas caused by the ischemic stroke is shown very clearly.

Table 1: a-Original image; b-Watershed over-segmentation using Sobel filter

Image Name	***a-Original Image***	***b-Watershed Over segmentation using sobel***
Patient 1		
Patient 2		
Patient 3		
Patient 4		

In Table 3, the CT image of patient1, who had an ischemic

Table 2: a-CT images of three Ischemic Stroke patients; b- after applying the Marker Controlled Watershed, c-Colored Watershed Matrix (Lrgb)

Image Name	***a-Original Image***	***b-Marker Based Watershed***	***c-Colored Watershed***
Patient 1			
Patient 4			
Patient 3			

stroke and the infarcted area, is on the left side of the brain. The marker-controlled watershed is applied and the minima markers is assigned and imposed on the foreground and background of the CT image. The minima markers is superimposed on the original image. After extending the minima and maxima, the stroke will be seen clearly, especially differentiation is difficult between the Gray-White Matter interface on the right side of the brain tissues and the infarcted region, which is colored and shown after getting the colored watershed matrix.

Table3: CT image of Ischemic Stroke patient after applying the Marker Controlled Watershed

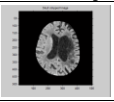
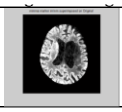
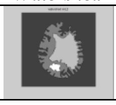
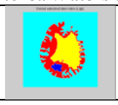
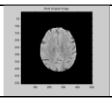
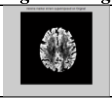
	
Extended Minima	***Extended Maxima***
	
Watershed	***Colored Watershed***
	

Table 4 contains the CT image of a normal patient. After applying the Marker Controlled watershed, the minima is superimposed on the original image and extended to segment the White Matter of the Brain, while the Maxima is extended to represent the Gray Matter of the brain and that was because it is a Normal patient where you can differentiate between the Gray-White Matter interface.

Table 4: CT images of Normal patient showing the extended minima and maxima.

Skull Stripped Normal Image	***Minima Marker Superimposed on Original Image***
	
Extended Minima as White Matter of Brain	***Extended Maxima as Gray Matter of Brain***
	

Conclusion:

The Marker Controlled watershed is an automatic method for segmentation of Medical images especially CT scan where results showed good segmentation of Ischemic stroke better than watershed segmentation especially it requires minimal user interference and that will help the non-radiologists to identify the infarcted regions of the brain tissues. I highly recommend to continue applying Marker controlled Watershed on Hemorrhagic stroke and do classifications of Normal and Abnormal Patient CT and to do the Graphical User Interface so the end user diagnoses the stoke cases from the non-enhanced CT images easily and fast.

References

[1] Jeffrey L. Saver, “Time Is Brain—Quantified”, Stroke. 2006; 37:263-266.J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[2] World Health Organization, http://www.who.int/topics/cerebrovascular_accident/en/K. Elissa, “Title of paper if known,” unpublished.

[3] American Heart Association, http://www.strokeassociation.org, Accessed on 9/3/2019. inistry of Public Health of Lebanon, https://www.moph.gov.lb/en/Pages/17/14403/hasbani-we-are-working-to-enhance-the-capacities-of-the-public-hospitalization-sector-14/10/2017, Accessed on 8/9/2018.

[4] N. Hema Rajini and R. Bhavani. “Computer aided detection of ischemic stroke using segmentation and texture features Measurement”, vol. 46, pp.1865–1874, 2013.

[5] Radiology Assistant, www.radiologyassistant.nl/en/p4befacb3e4691/cerebralvenousthrombosis.html, Accessed on 24/3/2019.

[6] Roman Peter, Panagiotis Korfiatis, Daniel Blezek, and A. Oscar Beitia, Irena Stepan-Buksakowska and Daniel Horinek, Kelly D. Flemming, Bradley J. Erickson, “A quantitative symmetry-based analysis of hyperacute ischemic stroke lesions in non-contrast computed tomography”, Medical Physics, 44 (1), January 2017.

[7] Amina Fatima Zahra Yahiaoui, Abdelhafid Bessaid, “Segmentation of Ischemic Stroke Area from CT Brain Images”, International Symposium on Signal, Image, Video and Communications (ISIVC) 2016.

[8] Alyaa Hussein Ali, Shahad Imad Abdulsalam, Ihssan Subhi Nema, “Detection and Segmentation of Ischemic Stroke Using Textural Analysis on Brain CT Images”, International Journal of Scientific & Engineering Research, Volume 6, Issue 2, February-2015 ISSN 2229-5518 IJSER

[9] Yeu-Sheng Tyan, Ming-Chi Wu, Chiun-Li Chin, Yu-Liang Kuo, Ming-Sian Lee, Hao-Yan Chang, “Ischemic Stroke Detection System with a Computer-Aided Diagnostic Ability Using an Unsupervised Feature Perception Enhancement Method”, International Journal of Biomedical Imaging Volume 2014.

[10] Tomasz Hachaj, Marek R. Ogiela,” Application of neural networks in detection of abnormal brain perfusion regions”, Neurocomputing, 2013 Elsevier B.V.

[11] Varsha Gupta, Wojciech Ambrosius, Guoyu Qian, Anna Blazejewska, Radoslaw Kazmierski, Andrzej Urbanik, Wieslaw L. Nowinski, “Automatic Segmentation of Cerebrospinal Fluid, White and Gray Matter in Unenhanced Computed Tomography Images”, Academic Radiology, Vol 17, No 11, November 2010.

[12] Tiong-Lang Tan, Kok-Swee Sim, Aun-Kee Chong, “Contrast Enhancement of CT Brain Images for Detection of Ischemic Stroke”, 2012 International Conference on Biomedical Engineering (ICoBE), February 2012.

[13] Isabela Maria de Carvalho, Crusoé Silva, Deborah Queiroz de Freitas, Glaucia Maria Bovi Ambrosano, Frab Norberto Bóscolo, Solange Maria Almeida, “Bone density: comparative evaluation of Hounsfield units in multislice and cone-beam computed tomography”, Oral Radiology, Braz. Oral res. vol.26 no.6 São Paulo Nov./Dec. 2012

[14] Scott E Umbaugh, “Digital Image Processing and Analysis Human and Computer Vision applications with CVIPtools”, CRC Press, Second edition.

[15] Scott E Umbaugh, “Digital Image Processing and Analysis Human and Computer Vision applications with CVIPtools”, CRC Press, Second edition.

[16] Christian Lucas, Andre Kemmling, Amir Madany Mamlouk, Mattias P. Heinrich,” Multi Scale Neural Network For Automatic Segmentation of Ischemic Stroke On Acute Perfusion”, 2018 IEEE 15th International Symposium on Biomedical Imaging (ISBI 2018).

[17] Radiopaedia,Internet:https://radiopaedia.org/articles/ischaemic-stroke, Accessed on 18/4/2019.

[18] Dr. DJ Jackson, “Computer Vision and Image Processing”, www.jjackson.eng.ua.edu/courses/ece482/lectures/LECT13- 2.pdf.

[19] Linda Shapiro, George Stockman, “Computer Vision”, March 2010.

[20] F. Y. Shih, Image processing and pattern recognition: fundamentals and techniques, 1st ed., New Jersey: Wiley, 2010.

[21] Fernand Meyer,” The watershed concept and its use in segmentation : a briefhistory”, 2012, Internet: https://www.researchgate.net/publication/221661175_The_watershed_concept_and_its_use_in_segmentation_a_brief_history Accessed 3/4/2019.

[22] Steve Eddins, “The Watershed Transform: Strategies for Image Segmentation”, Mathworks, Internet: https://www.mathworks.com/company/newsletters/articles/the-watershed-transform-strategies-for-image-segmentation.html, Accessed on 1/4/2019.

[23] Ahmad El Allaoui, M’barek Nasri,” Medical Image Segmentation by Marker Controlled Watershed and Mathematical Morphology”, The International Journal of Multimedia & Its Applications (IJMA) Vol.4, No.3, June 2012.

[24] University of Groningen, “Advanced Morphological Image Processing”, Internet: http://www.cs.rug.nl/~roe/courses/ip/9_morf2-handout, Accessed on: 4/4/2019.

[25] Rafael C. Gonzalez, Richard E. Woods, Steven L. Eddins, “Morphological Reconstruction From Digital Image Processing Using MATLAB”,MatlabDigest,https://ww2.mathworks.cn/tagteam/64199_91822v00_eddins_final.pdf, Accessed: 4/4/2019.