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Characterization of Brain Tumor Using Haralick Parameter and Tumor Volume Calculation

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Abstract: CT images have excellent bonny details with the ease of availability. But due to less contrast and details it is less studied. CT images of 5 tumor identified patient were procured. Then this study is divided into three parts. (1) Characterization of tumor using texture analysis. (2) Segmentation of the tumor and (3) volume calculation of the tumor. Preprocessing is important in order to remove the noise and further analysis of image. It is done via contrast enhancement and using median filter the noise is removed. In order to determine the image characteristic we applied texture analysis including Homogeneity, Correlation, Contrast, and Energy. Paired t-test using SPSS software is applied to find the significance of data of tumorous and non-tumorous image. Segmentation and extraction of tumor is performed via Watershed and Fuzzy c-means algorithms. Both the algorithms were evaluated for correctness and completeness. The watershed shows superiority over fuzzy c-means as it lacks robustness. Lastly, volume of the brain tumor is evaluated using MATLAB ® software and compared with the manual results.

Keywords: CT image, pre-processing, texture analysis, segmentation, Watershed, fuzzy c-means, volume calculation, SPSS.

1. INTRODUCTION

CT has become the centerpiece for cranial imaging. It is used for examination of choice for investigating stroke, intracranial hemorrhage, trauma and degenerative diseases CT has several advantages over magnetic resonance imaging (MRI). These include short imaging times, widespread availability, ease of access, ideal detection of calcification and hemorrhage and excellent resolution of bony detail. CT is also valuable in patients who cannot have MRI due to implanted biomedical devices. Limitations to CT scanning of the head include: artifacts because of beam hardening. Beside all these features study of CT images is sparse.

Texture of an image is high or low level in brightness, also called as Gray level indicated by window size. The landmark discovery in texture classification was first introduced by Robert M. Haralick (Haralick et.al., 1973). Their works contribute to the classification of an image into various textural parameters on the basis of which two images can be ordered different. The fresh concept of GSDM (Gray- tone Spatial Dependence Matrix) arises based on which 28 textural feature of an image came into existence. The main features are Homogeneity, Energy (ASM), Correlation, Entropy, Contrast, Sum entropy, Variance, Standard deviation etc. They experimented and calculated these feature on aerial photographs of different land mass. The results were highly acceptable with 80-90% of accuracy. A review on texture analysis on medical images shows the way the method works in detecting the various diseases through different modality (G. Castellano et. al., 2004). They demonstrated the problem and formula to solve all health related issue from segmentation of medical images to the detecting of lesions. The interrelation between the two medical images on basis of texture still lacks a cordial study. Segmentation is an important part of any image analysis procedure. There are number of segmentation algorithm method but to say which one superior than other is still totally depend upon the image and the way algorithm is written (Nikhil R. Pal et.al., 1993). Improved watershed segmentation was applied to segment MR image of brain (H.P. Ng. et.al. 2006). The gradient magnitude of the primary segmentation was done applying the Sobel operator. The rainfall simulation is applied on the improved edge map. It still need over segmentation to be removed. Watershed algorithm is better when intensity level difference between tumor and non-tumor images is higher. Rajeev Ratan et.al .segmented 2D and 3D MR images of brain having detected tumor. Segmentation of CT images is relatively sparse than the MR images (Alexandra Lauric et.al.2007). The purpose of this paper is to study three different segmentation methods; viz. Bayesian Classification, Fuzzy c-means and Expectation maximization on CT images. The author proposes the effectiveness of available algorithms on soft tissue segmentation of brain CT images. Fuzzy c-means develops many small clusters; to overcome this problem PDI (population diameter independent) algorithm is used. A study of different technique of evaluation was performed for the classification of performance measure of segmentation algorithm (Jayaram K. Udupa et.al. 2002). Image segmentation consists of recognition and delineation. They identified 13 different parameters on which the whole evaluation system is based and is necessary for any algorithm to pass on these criteria. Three evaluating factors were chosen viz. precision, accuracy and efficiency. This study encompasses image preprocessing to volume determination of brain tumor and segmentation via watershed and fuzzy c-means.

2. METHOD

A. Subject Selection

A total of 5 subjects were included in the study irrespective of gender and were identified having brain tumor. The age group is between 30-60 yrs. The thickness of the slices is 6mm as to reduce the radiation burden on the patient. Fig.1 shows the proposed method.

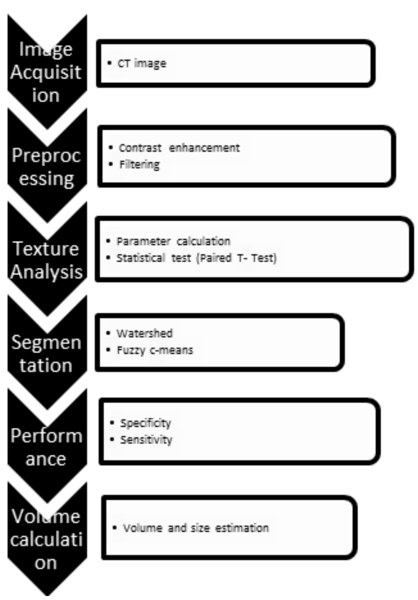


Fig: 1 Flow chart of Methodology

B. Pre-processing of Images

Preprocessing of the images is done in order to improve the quality of data for later analyses. Batch processing of image is performed for the ease of extraction of valuable information from the data.

The gray level window is adjusted optimum level so that visualization of tumor and other bony part made accessible for further applications. An image without histogram adjustment has 0 to 65535 distinct gray levels (16 bit).

Median filtering is considered ideal for the medical image processing for the removal of noises; especially for 'salt and pepper' type of noises and noises develop from metal artifact._Neighborhood value of 3-by-3 is considered to retain sufficient information and to preserve the edges.

C. Texture Analysis

Texture analysis refers to the classification of regions in an image by their texture content. It attempts to quantify spontaneous qualities described by terms such as rough, smooth, silky, or bumpy as a function of the spatial variation in pixel intensities. The GLCM (Gray Level Co-occurrence Matrix) is used for a series of "second order" texture calculations. Second order measures consider the relationship between groups of two pixels in the original image. Calculated texture is Homogeneity, Contrast, Energy and Correlation.

Table 1: Angle with offset values

Angle	Offset
0	[0 D]
45	[-D D]

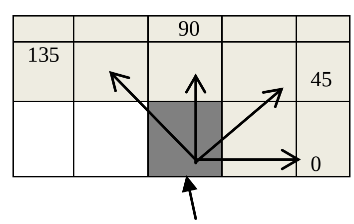


Fig. 2: Arrays of Offsets

Table 2: Textural Factors

Textural Calculations	Formula
Contrast	$\sum_{i,j=0}^{N-1} P_{i,j}(i-j)^2$
Homogeneity	$\sum_{i,j=0}^{N-1} \frac{P_{i,j}}{1+(i-j)^2}$
Energy	$\sum_{i,j=0}^{N-1} P_{i,j}^{2}$
Correlation	$\sum_{i,j=0}^{N-1} P_{i,j}\left[\frac{(i-\mu_i)(j-\mu_j)}{\sqrt{(\sigma_i^2)(\sigma_j^2)}}\right]$

Algorithm for textural analysis

- Creation of GLCMs
- Set Gray Co-Matrix
- Define 'Offset Value'
- Find the Normalization value.
- Find GLCMS for Homogeneity, Correlation, Energy, Contrast

Paired t-test is applied to test the significance between tumor and non-tumor image. The significance level is set at 95% ($p < 0.5$).

D. Segmentation

Watershed segmentation is a way of automatically separating apart particles that touch in a segmented (binary) image. It is taken from geographical context that when water starts filling in catchment basins dams are created, when these dames are completely filled ridge line or watershed line emerged. Regional minima and maxima are created.

FCM (Fuzzy c-means) is a method of clustering in which one piece of data belongs to one or more groups. In fuzzy c -means, the centroid of a cluster is computed as being the mean of all points, weighted by their degree of belonging to the cluster. Degree of being in a certain cluster is related to the inverse of the distance to the cluster.

1) Steps for Watershed Segmentation

Step 1: Read in the color image and convert it to gray scale.
Step 2: Compute a segmentation function. This is an image whose dark regions are the objects we are trying to segment.
Step 3: Compute foreground markers. These are connected blobs of pixels within each of the objects.
Step 4: Compute background markers. These are pixels that are not part of any object.
Step 5: Modify the segmentation function so that it only has minima at the foreground and background marker locations.
Step 6: Compute the watershed transform of the modified segmentation function.

2) Steps for Fuzzy C-Means

It is based on minimization of the following objective function:

$$J_m = \sum_{i=1}^{N}\sum_{j=1}^{C} u_{ij}^{m} ||x_i - c_j||^2$$

Step 1: Randomly select *'c'* cluster centers
Step 2: Calculate the fuzzy membership *'μ_{ij}'*
Step 3: Repeat step 2) and 3) until the minimum *'J'* value is achieved
Step 4: Compute the fuzzy centers

Where,
'n' is the number of data points
'c' represents the number of cluster centre
'm' is the fuzziness index m € [1, ∞]
µij' represents the membership of i^{th} data to j^{th} cluster.
'J' is the objective function.

E. Performance measurement

Comparison between two segmentation methods is done via detecting the completeness and correctness of the algorithm. The original figures were manually segmented called as ground truth is compared with algorithm segmented image.

Completeness is defined as the percentage of the ground truth region extracted by the segmentation algorithm and can be calculated using (G. M. N. R. Gajanayake *et.al.* 2009).

$$\text{Completeness} = \frac{TP}{TP+FN} * 100\%$$

Correctness can be defined as the percentage of correctly ground truth by the segmentation algorithm and can be calculated

$$\text{Correctness} = \frac{TP}{TP+FP} * 100\%$$

F. Volume Calculations

The area of the segmented image is calculated for all images of the tumor. Formula applied

Volume of tumor = Segmented area * slice thickness

3. RESULTS AND DISCUSSION

The CT images were processed using histogram equalization. After the adjustment of histogram properties the image is visible for human perception. One can easily identify the bony details in the image and can recognize the abnormality present.

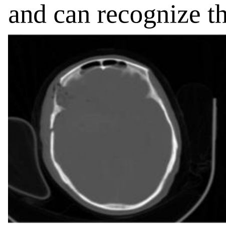


Fig3: Unprocessed Image

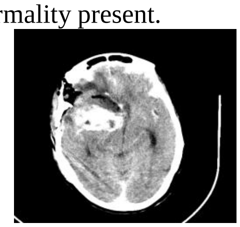


Fig 4: After contrast enhancement

Median filter with 3x3 neighbors is generally used for medical image processing. This filter efficiently removes noises preserving the image edge details.

A. Characterization of Tumor using Textural features of CT image

To characterize the tumor the four textural features Homogeneity, Correlation, Energy and Contrast were computed. These features give details about the similarity between the two images.

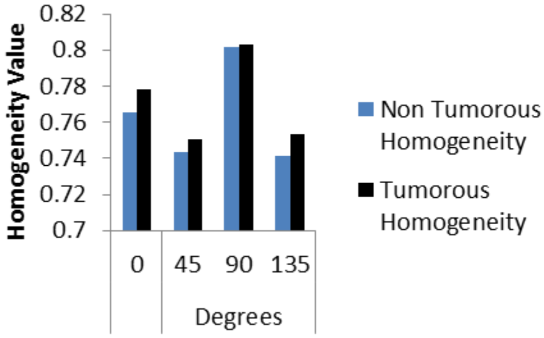


Fig 5: Comparison of Homogeneity between Non Tumorous and Tumorous CT Image

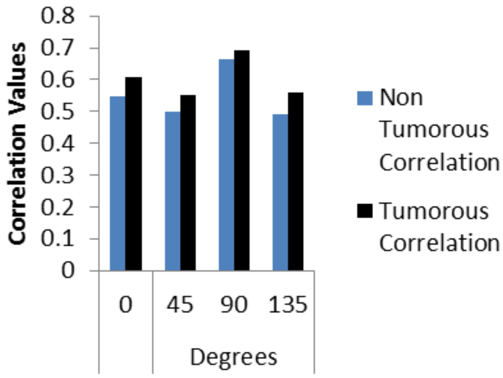


Fig 6: Comparison of correlation between Non Tumorous and Tumorous CT image

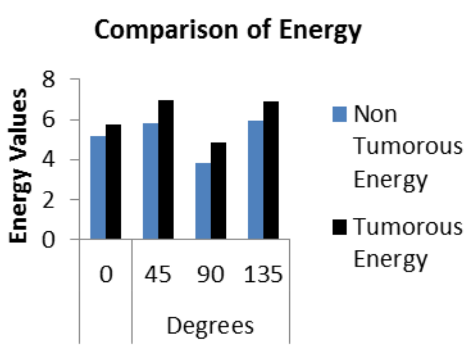


Fig: 7 Comparison of Energy between Non Tumorous and Tumorous CT image

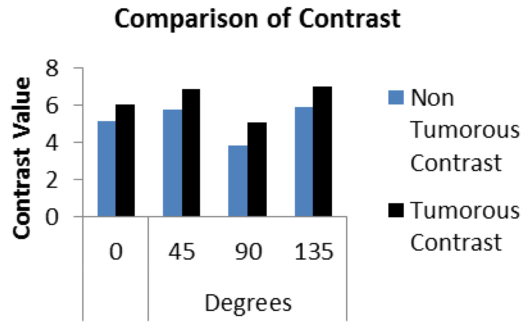


Fig 8: Shows comparison of Contrast between Non Tumorous and Tumorous CT image

B. Statistical comparison

Paired t- test was performed to compare statistical significance of textural features (homogeneity, correlation, energy and contrast) between tumor containing portion and non-tumor containing portion of image.

Table 3: Statistical comparison of textural features of tumor and non-tumor portion of CT image. Results considered significant at $p < 0.05$.

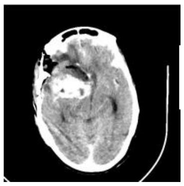
Comparison between	**Textural Feature**	**t- Value**	**p- Value**
Tumor and Non-tumor portion of image	Homogeneity	-3.360	0.044
	Correlation	-6.409	0.008
	Energy	-19.2 45	0.000
	Contrast	-7.362	0.005

Result showed differences in textural features of tumor containing and non-tumor containing portion of CT image were statistically significant In case of homogeneity $p<0.5$ which designates the consistency in the both figure were different due to presence of tumor. Correlation value indicates that when it is 0 the two figures are highly indifferent (Haralick *et.al.*, 1973). The result of correlation distinguish both the values of image are highly dissimilar. The energy content or the angular second moment of images is also significant. Energy of non-tumorous image is less while energy of tumor image is more, this shows that pixel variation and presence of brighter pixel is greater in tumor image. Same as in contrast the variation in pixel density is more in tumorous image than in non-tumorous one. Contrast and energy are correlated; more will be the contrast more will be energy content in the image. Texture parameters derived from gradient vectors and from generalized co-occurrence matrices for the characterization of texture of brain images, in order to demonstrate pathological conditions and normal condition were reported in literature (Kovalev *et al*., 1999)

C. Segmentation

Watershed and Fuzzy C-mean Segmentation algorithm are applied to tumor containing slice of CT images of 5 subjects.

Watershed Segmentation

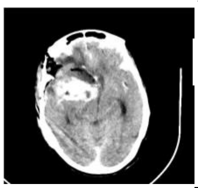


Segmentation →

Fig 9:
Enhanced CT image

Fig 10:
Segmented Tumor

Fuzzy c- means



Segmentation →

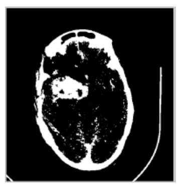


Fig 11:
Enhanced Image

Fig 12:
Segmented Image

D. Performance Measures

Table 4: Shows performance measure of watershed and Fuzzy C-mean segmentation methods

Segmentation Algorithm	**Completeness or Sensitivity**	**Correctness or Specificity**
Watershed Segmentation	98.7%	99.06%
Fuzzy c-means Segmentation	80.2%	98.09%

Above results shows that completeness of the watershed method is good than fuzzy c-means while correctness of both the algorithm are somewhat similar. The result symbolizes the superiority of watershed method over the fuzzy c- means. Performance of fuzzy c-means were earlier compared to other methods yielded high correctness but low completeness (G. M. N. R. Gajanayake *et. al.,* 2009)

E. Volume Calculations

Similarly after tumor region has been segmented using both segmentation techniques, the tumor volume calculations are performed in this segmented region. To calculate the volume of segmented tumor region, the automatic labeling of the entire volumetric tumor region has been done slice by slice and by calculating the total number of pixels into the labeled regions. Areas of the labeled region were calculated and multiplied by the CT slice thickness plus the inter slice gap to obtain a per-slice tumor volume. The total tumor volume was then obtained by summing the tumor-bearing slices. Relative error for tumor volume was also calculated.

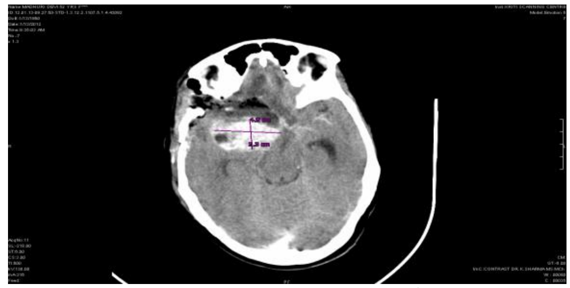


Fig 13: Manual dimensions marking of the tumor

Table 5 : Shows manually computed volume of tumor and automatic computed volume of tumor with % error.

Subject	Manual calculated volume (cm^3)	Automatic Calculated volume (cm^3)	% error
1.	5.7	5.02	11.9
2.	7.346	7.10	3
3.	4.179	3.928	6
4.	6.86	5.713	16.7
5.	2.04	2.00	1.9

4. Conclusion And Future Aspects

For any surgery to be done it is necessary to estimate the nature and depth of the tumor. Characterization of tumor shows that only texture of an image can reveal useful information to determine the abnormality at any level. We can identify significant differences between two images if they are not so visibly cleared or identifiable. The evaluated feature shows wide aspects to understand the medical images. Segmentation serves as a very strong tool for differentiating and separating two different objects in a same figure. For medical point of view the extraction of tumor with clarity and correctness are of utmost importance. Watershed and Fuzzy c-means proved to be good algorithm for medical image segmentation with modification is inevitable. The aspects of this work can be explored more. Texture analysis can be done on more parameters besides the 4 which we have chosen to understand the image better. Segmentation method can be modified and various other methods can be compared to know quality of image segmented. GUI (graphical user interface) environment has to be created on MATLAB® so that those are not well versed with MATLAB® can also access the software easily. 3D visualization of brain tumor can be done.

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