

## A Comparative Approach for Contour Detection of Brain Tumors by Using Image Correlation Techniques on tomography images

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### ABSTRACT

*In this study, contours of a brain tumor on a single slice tomography image were derived by using image correlation technique. Four different methods were used to compare the validity of the derived contours. Contour map of the brain tumor was generated by using 2D image correlation technique with raw pixel, perceived brightness (luminance), optical density and Relative radiation dose data. The resultant contour maps were the same in all methods. They produced the digital data for any remote surgical device to remove the tumor area.*

**Keywords:** Image Correlation, Radiation Dosimetry, Optical Density, Perceived Brightness, Contour Detection

### 1. INTRODUCTION

An abnormal mass of tissue which is not inflammatory and arises from cells of preexistent tissues is known as tumor.

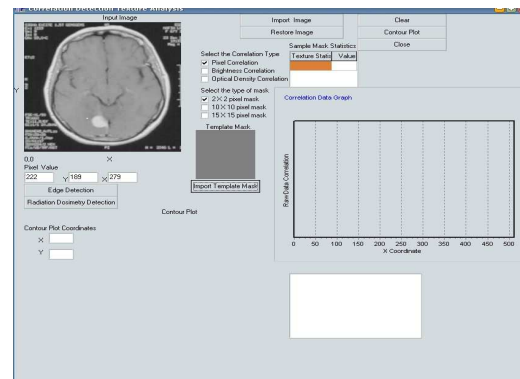
Determination of the brain tumor boundaries is an important issue in medical diagnosis [1]. Critical decisions are made in medical operations to treat the tumors. There are many techniques in literature to specify the boundaries of a brain tumor [2]. For instance; Conventional Radiology, Computer Aided Position Emission Tomography, Magnetic Resonance imaging, ultrasonography and etc. are all tumor detection systems which have been used to determine the regional boundaries of the tumors.

These detection systems use image information for detection. They scan the related body part with tumors at different cross sections and from different perspective angles to generate the 3 D view of that body part. Each cross section represented a slice image of the body part. Large number of these slices were gathered to generate the 3D structure of the body part with tumor .

A single slice computer tomography image was used to determine the contours of 2D brain tumor regions for the automated surgical devices. Different contour detection methods were employed together with image correlation technique to verify these contours.

### 2. MATERIALS & METHODS

An experimental menu driven software was developed with Borland C++ Builder V6.0 rapid application developer .**Figure-1** shows the menu which was used throughout this study ..



**Figure-1** The software menu which was used throughout the study.

A CT (Computerized tomography) scanner is a multi-beam X-ray device. It sends several beams simultaneously from different angles through the body. The X-rays from the beams are detected after they have passed through the body and their strength is measured. Beams that have passed through less dense tissues such as the lungs will be stronger, whereas beams that have passed through denser tissues such as bone will be weaker.

A computer can use this information to work out the relative density of the tissues examined. The relative density was calculated as the ratio of the incident and the exit X-ray beams on the tissues. These ratios were classified in a measurement scale for different tissues. [3].

Brain tumor area was made apparent in the image with a special tumor marker . This marker is a chemical substance which contained a special protein. This protein, in return, reacted with the tumor and showed the outlines of the tumor in CT image .

In this study, various brain slice images with tumor were taken with a Phillips Computer Tomography machine. Hardcopies of CT brain slice images were digitized and scanned in a bitmap form with a Vidar System Corporation VXR-16 film digitizer [4].

VXR-16 digitized the CT brain slices in 16 bit gray scale. Generated bitmap images were organized in 256 pixel x 256 pixel matrix form. Signal to noise ratio of VXR-16 was very low so that the content of the original image was protected during the digitization process. Pixel values in Brain slice images contained 256 intensity levels between 0 and 255. These values are identified as the raw pixel data.

**a) Image correlation with raw pixel data :**

Firstly, the image correlation technique was performed on the raw pixel data to determine the contours of the brain tumor. This technique was a cross correlation method. It compared a template of the image (the image correlation kernel such as a mask) with the actual camera image of an object and generated a new correlation image which stated where the template matched the camera image.

A sampling mask area, MxM pixel matrix across the image, was selected by the software and the same size reference mask area of the healthy brain tissue was used for cross correlation purposes. The reference mask was traveled horizontally across the brain slice image and at every location cross correlated with the sampling mask area [5]. This cross correlation technique was defined by the following formula [6].

$$f(x,y)*h(x,y)=1/(M*N)\sum\sum f*(m,n)h(x+m, y+n)$$

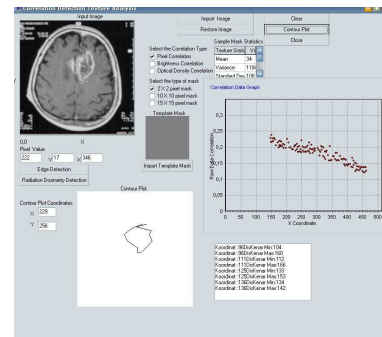
The above equation is a two dimensional discrete cross correlation algorithms where f(x,y) and h(x,y) represented the image sampling mask and the reference mask . Reference mask was moved on the image with various pixel sizes (3x3, 10x10, 15x15) and cross correlated with the same size sampling mask. Reference mask was identified as the average of the 5 same size masks across the healthy part of the brain on the same brain slice image. The resultant correlation coefficients were plotted against the scan positions across the image.

From the theory, the cross correlation of dissimilar points gives maximum peaks and similar points give minimum peaks.

Hence the generated maximum peaks in the correlation coefficient plots represented the transitions between the healthy and tumor areas. These maximum points were collected in an array. The first and the last maximum peaks in every scan corresponded to the healthy to tumor and tumor to healthy transitions respectively.

The first and the last maximum peaks for each scan represented also the outer boundary points of the tumor region. These peaks were filtered out by the software and later combined with lines to draw the 2D contours of the 2D brain tumor image as shown in **Figure-3**. These contours showed the border lines where the

healthy tissues ended and the tumor started. The contour spatial coordinates were stored in a file to be used by the surgical tools at a later stage.



**Figure-3** Contour of the brain tumor based on the image correlation technique with raw pixel data showed in white area. The actual correlation peaks are plotted with a shifted coordinate axes and showed in gray area.

**b) Image correlation with perceived brightness:**

2D contour of the brain tumor region in a brain slice image is obtained by using the perceived brightness (luminance) information. Perceived brightness (luminance) is the luminous intensity per unit area. Perceived brightness was computed from the intensity amplitudes of the pixels across the brain slice image. In this study, perceived brightness (luminance) value was calculated according to the following formula [7]:

$$\text{Luminance} = (\text{pixel value} / 255)^{\text{gamm}}$$

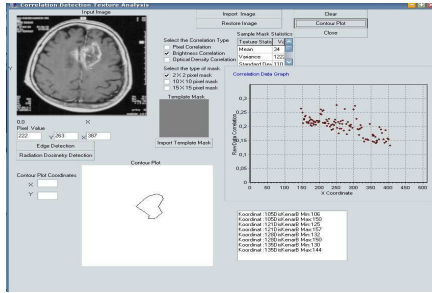
This formulation was used for the capture device such as a PC monitor. ‘‘Gamm’’ was a special function which depended on the average pixel response of the capture device. The images were displayed on PC Monitors and the specific ‘‘Gamm’’ value used for these monitors was 2.2. Calculated Luminance values for the sample mask together with their pixel values were tabulated in **Figure-4** .

Pixel Values	Perceived Brightness (Luminance) Values
192192192	545454
128128128	222222
128128128	222222

**Figure-4** Pixel intensity values and their corresponding Perceived Brightness values for 3x3 sample mask were tabulated.

The perceived brightness values of sample masks and the reference mask were calculated by the software. As the reference mask traveled horizontally across the brain slice image it was cross correlated with

the sample masks. Cross correlation peaks represented the transition between the healthy and tumor areas. Selecting and plotting the first and the last peaks by the software generated the horizontal contour points. Joining these contour points in 2D coordinates produced the 2D contours of tumors across the brain slice image. Contours were shown in **Figure-5**.



**Figure-5** Contour of the brain tumor based on the perceived brightness information showed in white area. The actual correlation peaks are plotted with a shifted coordinate axes and showed in gray area .

**c) Image correlation with optical density:**

2D contours of the brain tumors on a brain slice image were generated by using the optical density information. Optical density amplitude was calculated according to the following formula [8]:

$$OD_{\lambda} = \frac{A_{\lambda}}{L} = -\frac{1}{L} \text{Log}_{10} T = \frac{1}{L} \text{Log}_{10} \left( \frac{I_0}{I} \right)$$

$OD_{\lambda}$  denoted the optical density amplitude for a particular wavelength  $\lambda$ ,  $A_{\lambda}$  indicated the optical absorbance at wavelength  $\lambda$ .  $L$  was the distance that light traveled through the sample and measured in cm (i.e. the sample thickness),  $T$  was the per-unit “transmittance”.  $I_0$  was the intensity of the incident light beam and  $I$  was the intensity of the transmitted light beam.

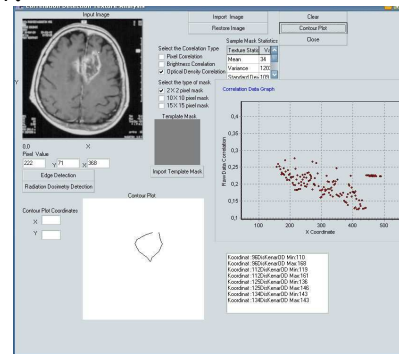
In this study,  $I_0$  values were taken as the pixel amplitude values of the brain slice image at different spatial coordinates and  $I$  was the maximum pixel amplitude value in the same brain slice image. Since the pixel amplitudes varied between 0 and 255,  $I$  was selected as 255.

$I_0$  pixel amplitude values of the brain slice image and  $I=255$  were used to calculate the optical density values corresponding to these pixel amplitudes with the above formula. An example of 3x3 sample mask containing pixel amplitudes and corresponding optical density amplitudes was shown in **Figure-6**:

Pixel Values	Optical Density Values
128128128	-0.30-0.30-0.30
128128128	-0.30-0.30-0.30
192192192	-0.12-0.12-0.12

**Figure-6** Pixel intensity values and their corresponding Optical Density values for 3x3 sample mask.

Similar image correlation technique was applied and the 2D contour of the brain tumor region on a brain slice image was generated as shown in **Figure-7**:



**Figure-7** Contour of the brain tumor based on the optical density information showed in white area. The actual correlation peaks are plotted with a shifted coordinate axes and showed in gray area .

**d) Image correlation with radiation dosimetry:**

Radiation dosimetry detection technique was combined with the image correlation technique to generate the 2D contour of the brain tumor in a brain slice image. Radiation dosimetry is a calibration technique for verifying the radiation dose quantities of the radiotherapy equipments. [9,10,11].

Radiation dose was a measure of the radiation penetrating the specimen (a tissue, an object etc.) during the filming procedure. This could be identified as the absorbed energy by the specimen. Radiation doses used in this part were computed by using the raw pixel information in the following formula [12,13]:

$$Dose(cGy) = b \sqrt{\frac{(PixelValue - Y_0 \times X_0^b - ax X_0^b)}{Y_0}}$$

$X_0$  and  $Y_0$  were the central coordinates of the sample masks considered for the dose calculations.

$a$  and  $b$  were the empirical coefficients that defines the environmental conditions such as temperature, film printing, humidity etc. These coefficients were taken as  $a=299.2$  and  $b=-1.02$  in this study.

“Gray” was a constant unit to measure the absorbed radiation dose. It was generally calculated in “centiGray” and denoted as “cGy” with respect to the

dimensions of the printed film. “Pixel Value” was the pixel amplitudes on the sample and the reference masks.

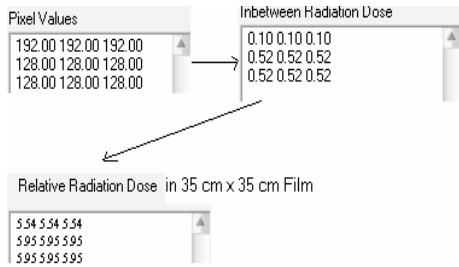
Initially, radiation dose was calculated for every pixel value in the sample and reference masks across the brain slice image by the above formula. These calculated radiation doses were calibrated with a mapping function for real films. This meant each computed radiation dose was converted into relative radiation dose for the real films of 35cmx35cm dimensions. The mapping function involves the conversion of the  $X_0$  and  $Y_0$  coordinates of the sample mask into centimeters (cm) as given by the following mapping function formula [14],

$$(x_0, y_0 \text{ values})cm = \left(\frac{\text{pixels}}{\text{dpi}}\right)x2.54$$

$X_0$  and  $Y_0$  values were calculated in cm and substituted in Dose equation to calculate the Relative Radiation dose values for every radiation dose .

“Dpi” denoted to “dots per inch” and depended on the display screen types. In this study 96 dpi was used due to the selected cathode display screen. “Pixel” was the intensity amplitude information of the sample and reference mask and 2.54 was the conversion coefficient between the inches to centimeters.

**Figure-8** displayed the pixel, calculated radiation dose and relative radiation dose values of the same sample mask for a 35cmx35cm film size.

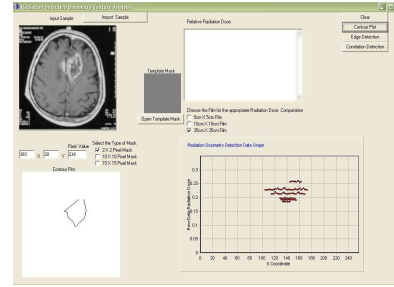


**Figure-8** 3x3 sample mask a) pixel amplitude values b) radiation dose values c) Relative radiation dose values for 35cmx35cm film

Similar image correlation technique was applied as before and the 2D contour of the brain tumor region on a brain slice image was generated by using relative radiation doses as shown in **Figure-9**.

### 3. RESULTS

Image correlation techniques were used with raw pixel data, perceived brightness (luminance), optical density and relative radiation dose information to generate 2D contour maps of the brain tumors in a



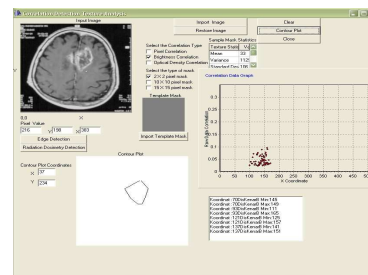
**Figure-9** Contour of the brain tumor based on the relative radiation dose information showed in white area. The actual correlation peaks are plotted with a shifted coordinate axes and showed in gray area.

a brain slice tomographic image . Same CT brain slice image with the tumor was displayed in this study for the readers with the developed software

Reference mask was moved across the brain slice image at the same coordinates in all methods. Same size (3x3) sample and reference masks were employed for correlation operations. 5 masks of 3x3 sizes were cropped from the healthy parts of the brain slice image and averaged to give the reference mask which was used in all methods.

Cross correlation between the sample mask and the reference mask generated the correlation peaks which corresponded to transitions between the healthy and tumor areas in all methods. It was clearly seen that the contours which were produced in all four methods were the same. They were compared according to their spatial coordinates and their contour shapes. There were no significant differences between them.

Finally all four contours were averaged by the software and a single contour of the brain tumor was generated for the surgeon as shown in **Figure-10** .



**Figure-10** Average Contour of the brain tumor across the brain slice image.

### 4. DISCUSSION AND CONCLUSION

A visual menu driven software was developed to assist the surgeons to digitally locate the brain tumors for their robotic surgical tools .

Algorithms were developed to use the CT or MR films and their intensity distributions across them.

Cross correlation techniques were implemented to determine the transitions between healthy and tumor brain areas. The results showed that the correlation algorithm based on raw pixel data, the perceived brightness (luminance), optical density and relative radiation dose values used in this study generated similar contour lines of the brain tumor region.

The techniques, introduced here, were similar to the other pattern extraction and identification techniques. These contour lines or the contour points across the brain slice image were stored in the computer, digitally, and they are made available to be used with robotic surgical tools.

The resultant contour data would be used with robotic surgical tools for tumor removal operations. The software and the introduced algorithms functioned well and showed time and memory efficiency performance among the other pattern extraction and identification algorithms.

The next step would be to interface and use this digital data in the form of contour maps to a robot arm and actually see the correct removal of the tumor. The algorithmic method used in this study would be a reliable and a beneficial method as a computer assisted medical image analysis method.

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