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3D Stereolithographic Reconstruction and Analysis of Brain Tumor from Magnetic Resonance Images



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Abstract:

The tumor is an abnormal mass of tissue found in Brain. Magnetic Resonance Imaging (MRI) 2D images of internal elements of the body. As 2D images never offer the particular feel of how a tumor precisely seems like. With the event of computer image process technology, 3D image has become a vital methodology of the medical diagnose, it offers superabundant and appropriate data for surgeons. So during this paper, we have a tendency to propose associate degree economical approach to 3D reconstruction of tumor and estimation of its volume from a collection of 2D cross sectional MR Images of the brain. Within the initiative, these images are preprocessed to enhance the standard of the image.

Next, abnormal slices are identified based on Histogram Analysis and tumor on those slices is segmented. Next, the proposed slice interpolation technique is applied to estimate the missing slices accurately and expeditiously. Then, the surface mesh of the tumor is reconstructed by applying the Marching Cubes (MC) algorithm on a collection of abnormal slices. Finally, rendering was performed on the reconstructed mesh to feature realism to the 3D model of the brain tumor. 3D Stereolithograph model enhances the standard of visualization and utility of surface image to help the radiotherapist find the tumor location, volume.

Keywords: Magnetic Resonance Imaging; 3-Dimensional; Segmentation; Marching Cubes.

I. INTRODUCTION:

Human brain is that the most significant and complicated organ of our central system. It is very necessary to convert available 2-D MR Images to a 3D brain image to see if there are any irregularities. 3D reconstruction of medical pictures is wide applied to tumor localization, surgical strategy and removing the necessity for rescanning. The brain MR pictures contain wide range of the gray-scales and extremely irregular boundaries. Thus it is tough to classify different tissues using existing strategies.MRI uses radio waves and magnetic fields to acquire a group of cross sectional images of the brain. The anatomic details of the 3D tumor are given as a set of 2D parallel cross sectional slices. Illustration of 3D information in the form of 2D projected slices will lead to loss of data and will result in inaccurate interpretation of results. Although radiotherapists are trained to interpret these images, they typically notice issue in communicating their interpretations to a physician, who could have issue in imagining the 3D anatomy. Hence, there is a necessity for 3D reconstruction of the tumor from a set of 2D parallel cross sectional pictures of the tumor. 3D visualization allows higher understanding of the topology and shape of the tumor, and allows measurements of its geometrical characteristics.

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PROPOSED ALGORITHM

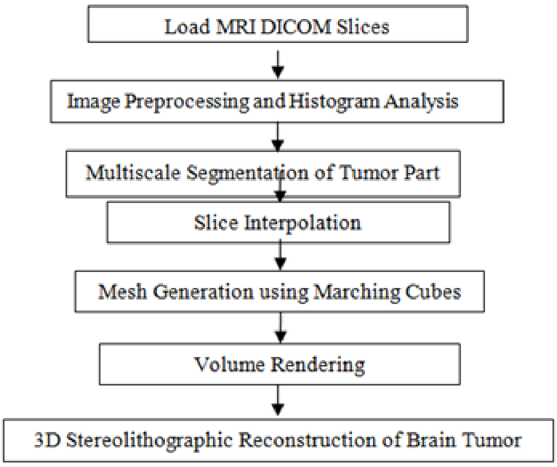

Fig. 1. Flowchart for Stereolithographic reconstruction

A. DICOM Slices

B. Digital Imaging and Communications in Medicine (DICOM) may be a commonplace for handling, storing, printing, and transmittal data in medical imaging. It includes a file format definition and a network prescript. The communication protocol is associate application protocol that uses TCP/IP to interact between systems. DICOM files are often changed between two entities that are capable of receiving image and patient information in DICOM format. The National Electrical Manufacturers Association (NEMA) holds the copyright to the present standard. It absolutely was developed by the DICOM Standards Committee, whose members also are partially members of NEMA.

C. Preprocessing of Image and Histogram Equalization

Preprocessing of Image is performed to boost the standard of the non heritable pictures. The noise will mask and blur the vital options in the Magnetic resonance Image and therefore create further steps in medical image analysis troublesome. Hence, to boost the perceptibility of the tumor and alternative structures within the brain, Gaussian filtering is used. Image contrast is increased by applying Histogram Equalization.

The traditional normal slice consists of three regions White Matter (WM), Gray Matter (GM) and Cerebrospinal fluid (CSF). Where as a slice with tumor consists of four regions (WM, GM, CSF and tumor). Therefore so as to see whether or not the given MR image of the brain is normal or abnormal, the histogram of the brain region is computed. If the Histogram consists of three peaks then the given MR image is taken into account as the normal slice and more process of the MR image isn't dole out. Otherwise, we tend to consider that the slice contains the abnormal region and proceed to use segmentation.

Consider a discrete grayscale image {x} and let n_i be the number of occurrences of gray level i. The probability of an occurrence of a pixel of level i in the image is given in Eq. (1)

$$p_x(i) = p(x=i) = \frac{n_i}{n}, \quad 0 \le i < L \qquad (1)$$

Where L being the total no. of gray levels in the image (typically 256), n being the total number of pixels in the image, and $p_x(i)$ being in fact the image's histogram for pixel value i, normalized to [0,1].

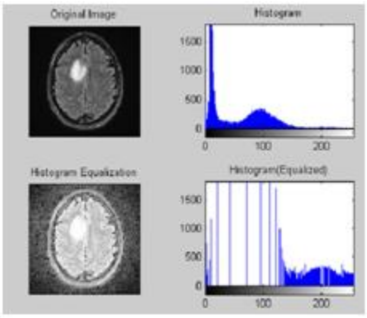

Fig. 2. Histogram of an image before and after Equalization

D. Multiscale Segmentation:

Thresholding is that the simplest methodology of image segmentation. From a grayscale image, thresholding may be used to produce binary pictures, in order that objects of interest are isolated from the background. Throughout the thresholding method, individual pixels in a slice are marked as "object" pixels if their value is greater than few threshold values (assuming associate object to be brighter than the background) and as "background" pixels otherwise.

MRI of the brain offers a group of slices containing normal and abnormal slices. Hence, before segmentation we would like to spot the abnormal slices containing the tumor. The conventional slice consists of three regions white matter (WM), gray matter (GM) and cerebrospinal fluid (CSF). Whereas a slice with tumor consists of four regions (WM, GM, CSF and tumor). So as to see whether the given MR image of the brain is normal or abnormal, the histogram of the brain region is computed using the given equation and also the variety of clusters present within the brain region is set supported based on Histogram analysis given by Eq. (2)

$$h(g) = \frac{\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}\delta(I(x,y)-g)}{M \times N} \quad (2)$$

Where, the function h(g) gives the number of pixels having a gray level equal to g in the image of size M×N. The gray level g lies in the range [0:L-1] and L is the maximum gray level in the image. Function δ(0) = 1 and δ (g≠0) = 0.

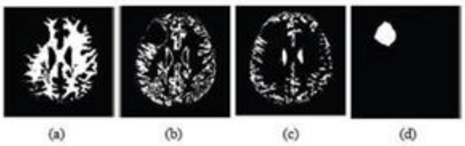

Fig. 3. Clusters of the Brain in MR Image: (a) White Matter (b) Gray Matter (c) Cerebrospinal Fluid (d) Tumor

E. Slice Interpolation:

After the segmentation, slices of the segmented tumor are unit stacked up to create the volume information within the 3D area. Generally, the set of slices extracted from the MRI device is such the gap between the slices is larger than the gap between the pixels within the slice. The surface reconstructed with such a collection of slices is inaccurate and not sleek. Therefore during this work, the missing slices are predicted using interpolation technique shown in Fig. 4

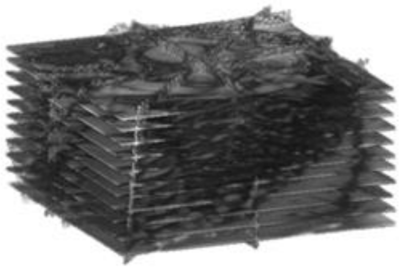

Fig. 4 Slice Interpolation

F. Mesh Construction using Marching Cubes (MC)

Once we have got the whole set of slices, we have a tendency to apply the MC algorithmic rule projected by Lorensen to reconstruct 3D surface of the tumor from a group of 2D cross sectional pictures. The MC algorithmic rule operates on a logical cube created from eight pixels; four each of two adjacent slices. It processes one cube at a time and determines how the surface intersects every cube using the isovalue of the surface and cube-isosurface intersection patterns shown in Fig 5. The matter with these patterns is that there is an chance of ambiguous faces and therefore holes form within the reconstructed surface. An ambiguous face is the one that has an intersection in every of its four edges. During this case, the topologically correct affiliation between the intersection points becomes ambiguous, that ends up in the hole problem with Marching Cubes.

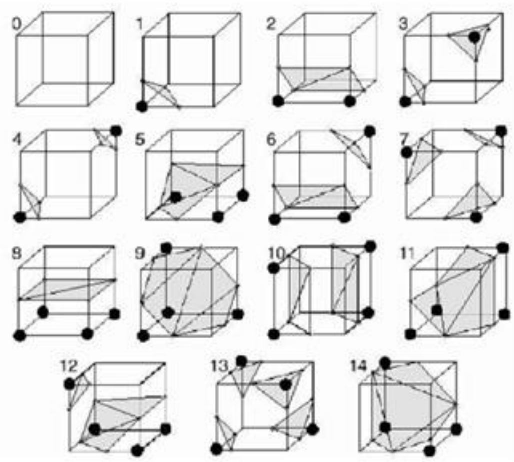

Fig. 5. Basic Cube-Isosurface Intersection Patterns

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It was determined that solely patterns 3, 6, 7, 10, 12 & 13 have ambiguous face and therefore modification was needed just for these patterns. So as to solve the hole problem in these patterns, we tend to utilized the strategy developed by Montani. By this methodology, the extra six patterns shown in Figure 6 that are complement of patterns 3, 6, 7, 10, 12, 13 were added to the list of basic fifteen patterns. Thus, we tend to consider total twenty one patterns to spot cube-surface intersection within the method of surface reconstruction of the tumor. With the assistance of intersection points and cube-isosurface intersection patterns the mesh of triangles was generated to represent the 3D surface of the tumor.

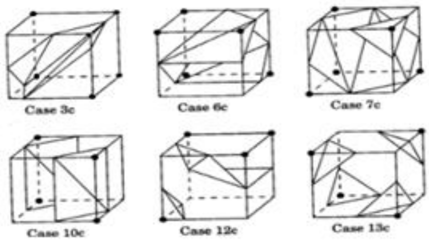


Fig. 6. Cube Configurations to Solve the Ambiguity Problem

G. Volume Rendering:

In the final step, realistic effects are supplemented to the surface of the 3D model by applying Ray casting Model. First the normals of triangle vertices within the mesh are computed by taking the common of the adjacent triangle normals. Then the shading model linearly interpolates the vertex normal and so applies the lighting model at every purpose on the surface to see the intensity at that point and therefore shades the complete surface.

II. 3D VOLUME RECONSTRUCTION:

Image reconstruction is the method of mapping the radio activities as a function of location for parcels or bits of tissue and can be created and planned (converting the 1D protection to cross sectional image). The image plane fashioned between 2 crystals within the same ring (n: Direct plane) or between 2 crystals in adjacent rings (n-1: Cross plane) produces (2n-1) image planes.

Coincidence events will be classified into projections pictures (called sinograms). If the septa between crystals removed, the number of planes is going to be n x n that produces the 3D. The volume of tumor is the very important data which will be extracted from the 3D model of tumor for knowing the severity of cancer and treatment strategy. In this work, the volume of the tumor is calculable by considering the slice thickness, inter-slice gap and area of the tumor on every abnormal slice as given within the following Eq. (3).

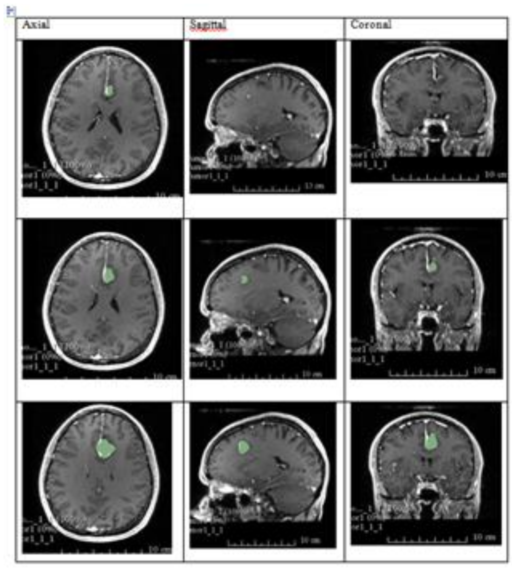
$$\text{Tumor Volume}=(\text{Interslice gap} + \text{slice thickness}) * \sum_{i=1}^{n} A_i$$

Where, n indicates the total number of slices containing tumor and A is the area of tumor on each slice which is calculated by

A_i = No.of pixels on slice i * Pixel dimension

III. EXPERIMENTAL IMPLIMENTATION:

The proposed technique was tested for many slices of brain Magnetic Resonance Images. The area of the detected tumor has been calculated for every slice. Later the tumor has been represented in three-dimensional (3D) view by stacking all the slices, and at last the volume of tumor has been analyzed. Volume of the tumor is 64.25mm^3.



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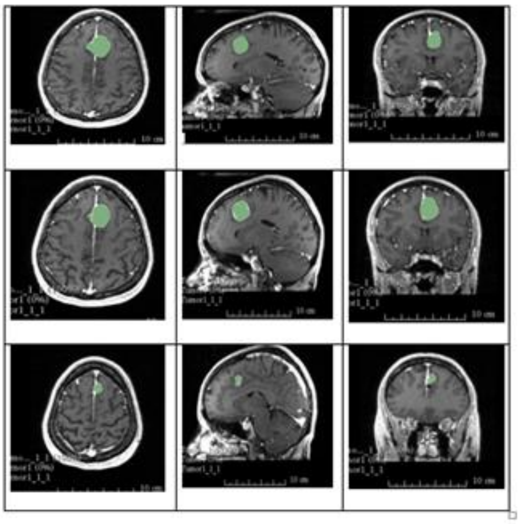

Fig.7. Slices having Tumor after Multiscale Segmentation

After the brain tumor segmentation, 2D tumor contours are organized specifically in real spatial positions. This forms the volume data of the tumor. Fig. 8 shows the meshing results when applying Marching Cubes (MC) algorithmic rule.

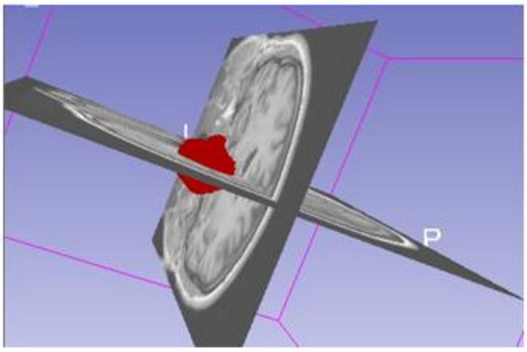

Fig. 8. 3D reconstruction of Tumor using Marching Cubes

The surface of the brain may also be reconstructed using the similar 3D reconstruction approach however by considering the brain region rather than tumor region. Using our planned approach numerous kinds of cuts may also be performed on the brain by the radiotherapist so as to know the tumor growth as shown in Fig. 9.

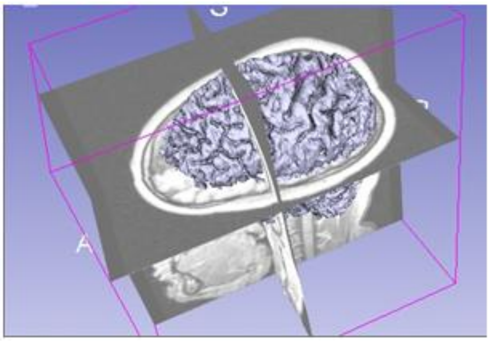

Fig. 9. 3D reconstruction of Brain using Marching Cubes

The surface of the brain with tumor is reconstructed using the 3D reconstruction Volume Rendering approach by considering the brain region and conjointly the tumor region. The rendered 3d reconstructed Brain with tumor is shown in Fig. 10.

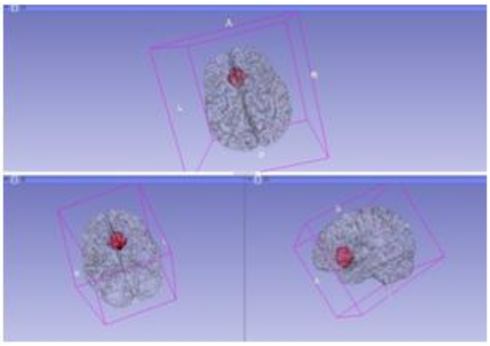

Fig. 10. 3D Stereolithographic reconstruction of Brain with Tumor after Rendering

IV. CONCLUSION:

The aim of this paper was to develop a 3D reconstruction and quantification approach for aiding the doctor in surgical strategy planning and volume computation of the tumor. The 3D model of the tumor was reconstructed from a given set of 2D slices of the brain by developing strategies for segmentation, inter-slice interpolation, mesh generation and simplification. Slices containing tumor were extracted from a given set of slices of the brain and therefore the tumor was segmented with the proposed multiscale segmentation technique. The centroid alignment technique in the proposed enhanced shape based interpolation helped in accurately estimating the missing slices by handling the shifts within the cross sections and therefore the inclusion of the chamfer distance rework improved the potency of shape based interpolation technique. Rendering part was accelerated by simplifying the mesh with the planned mesh simplification algorithmic program. The reconstructed growth was additionally quantified by measure its volume. The experimental results showed that our proposed 3D reconstruction approach will generate an accurate 3D model in less amount of time and therefore will assist the specialist within the diagnosing, identifying the stage of the tumor and treatment coming up with.

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