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Analysis of 2D to 3D Reconstruction Techniques over Brain MRI

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ABSTRACT: Human brain is the command centre for nervous system. Brain is a collection of soft spongy tissues. Research depicts that there are more than four hundred neurological diseases have been found till now. People dying because of these diseases are spiking now a days. Data shows five hundred to hundred million people dying around the world because of these brain diseases. Most commonly used image modality, to identify the brain abnormalities are Magnetic Resonance Imaging. Analysing MRI is necessary to take decisions regarding the disease. This paper takes 2D brain MRI DICOM images as an input and performs various segmentation and 3D reconstruction techniques to build a 3D model. Performance metrices are used to define, which segmentation and 3d reconstruction technique builds a 3d brain model efficiently. And the 3D model provides highly sophisticated view of human brain, and acts as a supporting aid for the doctor in the treatment process.

KEYWORDS: Brain MRI, segmentation, 3D reconstruction.

I. INTRODUCTION

Human brain is one of the largest and most complex organs in the body. Brain is made up of many cells, including neurons and glial cells. There are several diseases affect the brain. They are Parkinson's disease, Autism, Meningitis, Alzheimer's, Hydrocephalus, Brain Tumors etc. Brain tumor is one of the most dangerous diseases. Brain tumors can be classified into two types, benign and malignant. Benign tumor consist non cancerous tissues and malignant tumor consists of cancerous tissues, and it also affects the healthy brain cells. The modalities used to acquire brain images are MRI, CT, PET, and SPECT. This paper takes brain MRI DICOM image as an input. The common classifications of brain MRI are grey matter, white matter and cerebrospinal fluid. The input image is segmented for 3d reconstruction.

Segmentation can be defined as extraction of information from ROI (Region Of Interest) in the input image. There are several segmentation techniques are available such as global threshold, adaptive threshold, Otsu threshold, K means, fuzzy c means, seeded region growing, expectation maximization etc. The rendering techniques are used to construct the 3d model. There are two types of rendering, (i). Surface Rendering and (ii). Volume Rendering. The difference between surface and volume rendering is, in surface rendering it renders only the external surfaces it does not concentrate in it internal details where as in volume rendering it renders the volumetric details.

This paper uses volume rendering technique to reconstruct the 3D brain model. Volume rendering was further classified into two types Direct Volume Rendering (DVR) and Indirect Volume Rendering (IVR). The difference is direct volume rendering directly constructs the 3d model where in indirect volume rendering uses an intermediate surface to construct the 3d model. Example for indirect volume rendering is marching cubes, and direct volume rendering is shear wrap, splatting and ray casting. The 3d representation provides better understanding about the shape and topology of human brain. The organization of paper as follows; section III provides the proposed work of 2D to 3D reconstruction, section IV details experimental results & evaluation and section V concludes the result.

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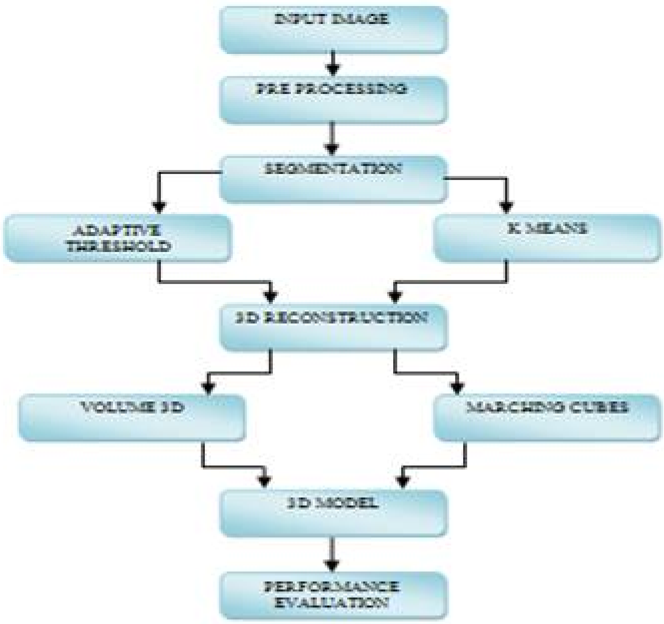
II. Related work

This section elaborately discussed about the previous achievement in the field of 3D brain modelling. Every image consists of image elements called, pixel in 2D and voxel in 3D space. Each image element have its own intensity and location, pixel is represented by (x, y) and voxel is represented by (x, y, z) where x and y represents the number of row and column in the image, and z represents the slice number in a volumetric stack [10]. Image pre-processing is the process of eliminating unwanted distortions and enhancing the image quality. Several image pre processing techniques are available they are, bias field correction, low resolution , simulation , presence of image artifacts , geometric distortion , low contrast , high level of noise[8]. Segmentation can be grouped under manual segmentation, intensity based methods (including thresholding, region growing, classification and clustering), atlas based methods, hybrid segmentation method, surface based methods (including active contours and surfaces, and multiphase active contours) [10]. Paper [1][5][11] uses the marching cubes algorithm and paper[2][4][9] uses the volume 3d technique to build a 3D model. However segmentation techniques and pre-processing approaches may vary. In paper [1], the author Himani S. Bhatt, Sima K. Gonsai has proposed active contour model and in paper [5], the author uses the fuzzy c means clustering technique to segment the brain MRI. In paper [2][4][7] the authors has used region growing, threshold and morphological operations to segment the DICOM images. The most commonly used 3D reconstruction technique is volume 3D and marching cubes. In this paper we have used two segmentation techniques adaptive threshold and k means clustering technique to segment the DICOM MRI brain images and marching cubes and volume 3D technique for 3D reconstruction.

III. Proposed method

The flow chart of converting 2D MRI to 3D brain model is given below,



A. *Input Image:*

The proposed method takes brain MRI DICOM images as an input. The input data set contains twenty three slices of two dimensional brain MRI images.

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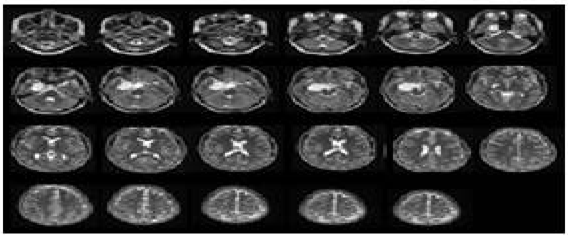

Fig.1. Input brain MRI DICOM images

B. *Pre processing:*

Aim of the proposed algorithm is to maximize the network life by minimizing the total transmission energy using energy efficient routes to transmit the packet. The proposed algorithm is consists of three main steps.

- Bias field correction:
  MRI images can be affected by magnetic field variations. This may be results in the intensity non Uniformities. Correction of this bias field is necessary for better result.

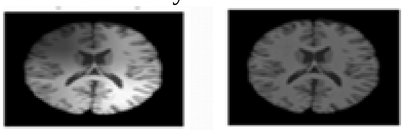

Fig.2. Image Before and After Bias Correction

- Gaussian low pass filter:
  Every image is affected by some sort of noise. Gaussian low pass filter is used to remove noise in the brain MRI images. Low pass filter is smoothing or blurring filter used to blur the image. Because the noise has highest intensities. The low pass filter calculates the average of a pixel by considering all of its eight neighbours. The result is replaced in the center pixel. This process will be repeated for every pixel in the image.

Fig.3. Image Before and After Pre Processing

C. *Segmentation*:

Segmentation is the process dividing a digital image into constituent parts or meaningful segments which helps to extract the quality amount of information in the region of interest. Two types of segmentation is used in this paper.

- Adaptive Threshold:
  Adaptive threshold takes color or grayscale image as an input, and outputs a binary image. The assumption behind adaptive thresholding is, smaller regions have more over uniform illumination. The adaptive threshold subdivides the image into smaller regions. Threshold is calculated using histogram for every smaller region in the image. Based on the threshold that particular region will be segmented. This process will be repeated for every sub divided partitions in the image.

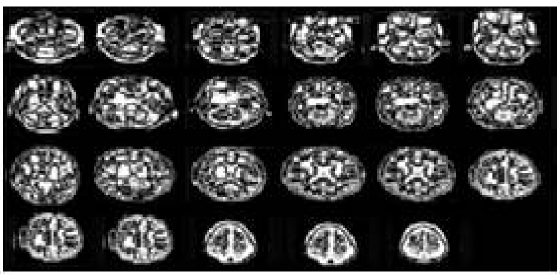

Fig.4. Adaptive segmentation over Pre-processed input images

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- K means clustering:
  It is an unsupervised learning technique. k is an number of clusters defined by the user. The algorithm randomly chooses k centroids, and calculate the Euclidean distance between the centroids and every pixel of image. Based on the distance it will form clusters. Compute mean for every clusters and re assign the centroids repeat the step until centroids does not move. i.e. there is no new centroids found.

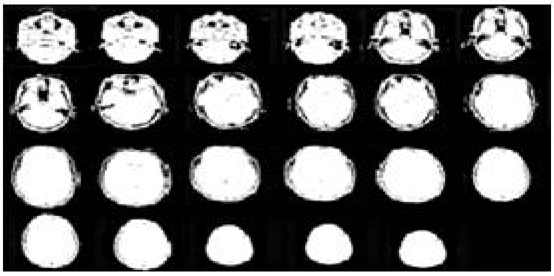

Fig.5. K Means segmentation over Pre-processed input images

D. *3D Reconstruction*:

This paper concentrated on two types of volume rendering techniques to construct a 3D brain model

- Volume 3D:
  Volume 3D function uses the 2D orthogonal plane texture mapping technique for volume rendering. It uses the fast open GL hardware. Before performing rendering operation the 2D input slices are stacked. All slices should be in same dimension. The steps involved in constructing 3D models from 2D slices are 1). Construct an empty space for 3D volume. 2). Each pixel coordinate in 2D image is represented by x and y. Distance between each slice is represented by z coordinate. If a pixel is adjacent to another pixel, then the 3D points will be connected together. 3). Repeat the steps to every slice for 3D volume rendering.
- Marching cubes:
  Marching cubes algorithm was developed by William E. Lorensen and Harvey E. Cline. It works on a scalar field. Steps involved in marching cube algorithm are, 1). Load series of input images into the memory. 2). Scan two slices and construct the cube using the eight pixels, four neighbors from one slice and another four neighbors from second slice. 3). Iso value is defined and each corner is classified. If all the corner is above the iso value then the cube is outside the object boundary. If all the corner is below the iso value then the cube is inside the object boundary. And it is a Boolean value. For eight corner, it may have 2^8 = 256 possible corner configurations. 4). If one or more pixels of a cube have values less than or greater than the iso value depicts that, part of the cube is contributing in the object representation. 5). By identifying which edges are intersected by the iso surface, we can create triangular patches. This can be accomplished by using look up table for cube iso surface intersection pattern. 6). By connecting the patches from all the cubes, surface representation is obtained.

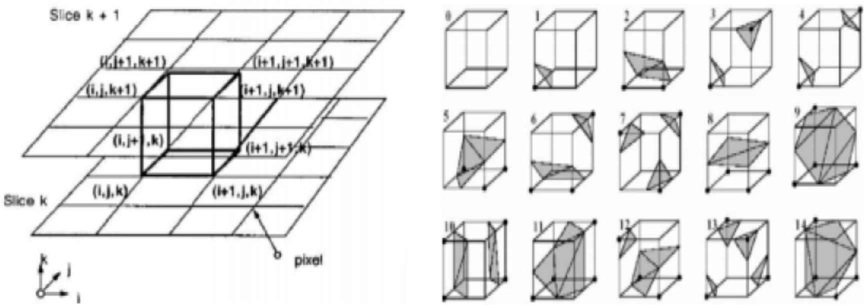

Fig.6. Cube-Iso surface Intersection Patterns

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IV. Experimental Results And Evaluation

The obtained result is evaluated by using the following metrices, Volumetric Overlap Error (VOE), Relative Volume Difference (RVD), Average Symmetric surface Distance (ASD), Maximum Symmetric surface Distance (MSD), Accuracy (ACC), Sensitivity (SEN), Specificity (SPEC), Precision (PREC), F Score. 'A' represents segmented image volume and 'B' represents the reference image volume.

$$VOE = \left(1 - \left(\frac{|A \cap B|}{|A \cup B|}\right)\right) \qquad RVD = \left(\left(\frac{|A| - |B|}{|B|}\right) \times 100\right) \qquad ASD = \frac{1}{|A| + |B|} \times \left(\sum_{x \in A} d(x, B) + \sum_{y \in B} d(y, A)\right)$$

$$MSD = (\max\{d_H(A, B), d_H(B, A)\}) \qquad ACC = \frac{TP+TN}{No.Of.Voxels} \qquad SENS = \frac{TN}{TP+FN}$$

$$SPEC = \frac{TN}{FP+TN} \qquad PREC = \frac{TP}{TP+FP} \qquad FSCORE = 2\,\frac{precision.recall}{precision+recall}$$

The 23 series of DICOM input images are pre processed and segmented before converting into a 3D model. Four types of 3D model is obtained from two different segmentation and two 3D reconstruction techniques. They are adaptive with volume 3D, k means with volume 3D,adaptive with marching cubes, k means with marching cubes.
Accuracy, sensitivity, specificity, precision are calculated for series of images, segmented using adaptive and k means segmentation techniques.

Table. 1. Performance Analysis of Adaptive Segmentation over Brain MRI DICOM images

ID	ACC	SEN	SPEC	PREC
1	71.3875	73.4378	53.3022	93.2758
2	69.3950	71.5571	51.5607	92.4157
3	68.9675	71.9762	44.4114	91.3553
4	65.6225	68.0852	46.6100	90.7794
5	67.4825	68.0868	62.4942	93.7445
6	64.6650	64.9154	62.7093	93.1491
7	66.4300	64.5718	80.8543	96.3208
8	65.5050	63.7461	81.4275	96.8820
9	63.6950	62.7553	72.6081	95.6006
10	63.3150	61.4771	79.6296	96.4015
11	61.5675	59.9141	75.8049	95.5203
12	61.3250	59.9739	73.4648	95.3068
13	59.5650	59.0463	64.4398	93.9775
14	59.8125	59.4741	63.2670	94.2945
15	59.5875	59.6539	58.8769	93.9470
16	62.0425	62.8903	52.9013	93.5053
17	64.0825	65.9578	41.2578	93.1815
18	66.8050	68.5109	44.7844	94.1233
19	72.8900	74.0046	57.6613	95.9809
20	76.9800	77.6487	66.8682	97.2559
21	84.9300	86.0389	65.8946	97.7428
22	83.2675	85.0858	42.8239	97.0674
23	93.6700	94.8004	64.9736	98.5654
MEAN	68.3908	68.8525	61.2446	94.7997

Table.2. Performance Analysis of K means Segmentation over Brain MRI DICOM images

ID	ACC	SEN	SPEC	PREC
1	82.6450	85.6654	56.0029	94.4978
2	85.0100	88.5774	55.5838	94.2693
3	80.7950	83.7992	56.2758	93.9912
4	82.9250	85.8159	60.6061	94.3877
5	77.5050	79.0067	65.1087	94.9219
6	81.2450	82.6622	70.1762	95.5847
7	81.3125	82.7092	70.4710	95.6028
8	86.0400	86.8244	78.9394	97.3905
9	87.6975	88.6251	78.8991	97.5513
10	90.4525	90.9680	85.8765	98.2810
11	91.2975	92.2568	83.0370	97.9093
12	91.1750	91.9348	84.3485	98.1405
13	90.3905	91.4945	80.0624	97.7338
14	91.3825	92.6985	77.9490	97.7227
15	91.3475	93.1577	71.9801	97.2657
16	93.1750	95.3394	69.8380	97.1495
17	94.6500	96.5722	71.2545	97.6127
18	96.3775	98.4323	69.8540	97.6824
19	96.9350	99.1495	66.6789	97.5993
20	95.3525	98.1076	53.6880	96.9730
21	95.9605	98.3782	54.5413	97.3786
22	96.2775	98.1948	53.6316	97.9211
23	97.4900	99.2205	53.5620	98.1897
MEAN	89.4542	91.2865	68.1898	96.7720

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The four types of 3D model, constructed using two different types of segmentation and reconstruction techniques are given below.

Fig.7. 3D model constructed using Adaptive Segmentation & volume 3D technique

Fig.8. 3D model constructed using K Means segmentation & volume 3D technique

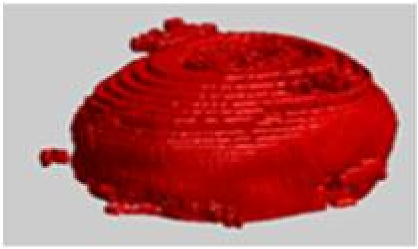

Fig.9. 3D model constructed using Adaptive Segmentation & Marching Cube Algorithm

Fig.10. 3D model constructed using K Means segmentation & Marching Cube Algorithm

Volumetric Overlap Error (VOE), Relative Volume Difference (RVD), Average Symmetric surface Distance (ASD), Maximum Symmetric surface Distance (MSD), Accuracy (ACC), Sensitivity (SEN), Specificity (SPEC), Precision (PREC), F Score are calculated for the four 2D to 3D reconstruction techniques.

Table.3. Performance Analysis for 2D to 3D Conversion Techniques

TECHNIQUES	VOE	RVD	ASD	MSD	ACC	SEN	SPEC	PREC	FSCORE
Adaptive with volume 3D	16.8585	20.2769	0.83591	0.15389	84.6105	86.0426	73.8985	96.1027	90.7948
Kmeans with volume 3D	10.7671	12.0662	0.86371	0.098288	90.1712	91.1968	81.5938	97.6436	94.3102
Adaptive with marching cubes	26.0949	35.3087	0.79375	0.23821	76.179	77.9746	64.6529	93.404	84.9947
Kmeans with marching cubes	2.6067	2.6765	0.90096	0.023796	97.6204	97.9037	94.8214	99.4676	98.6794

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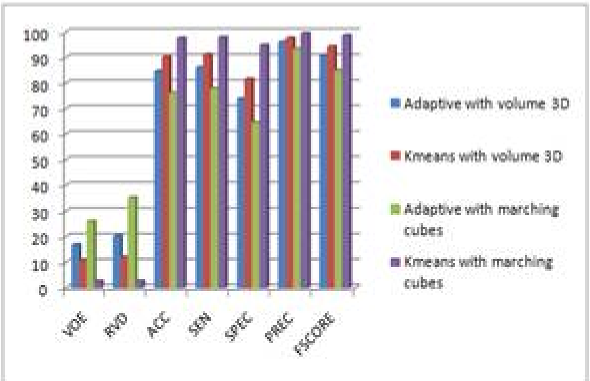

Fig.11. VOE,RVD,ACC,SEN,SPEC,PREC,FSCORE For 2D to 3D Conversion Techniques

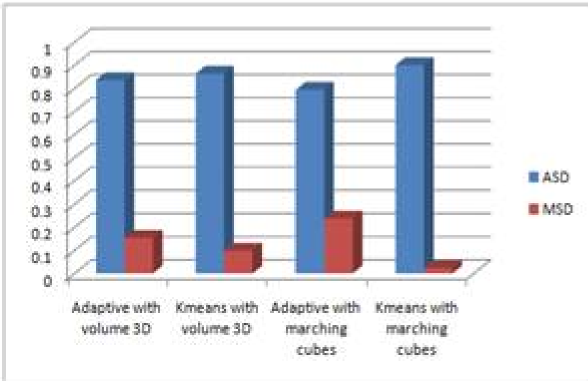

Fig.12. ASD & MSD of 2D to 3D Conversion Techniques

V. CONCLUSION

The 2D brain MRI DICOM images are taken as an input. Adaptive threshold and K means clustering techniques are used to segment the input images. Volume 3D and Marching Cubes Algorithm are used, to convert the segmented input images into a 3D model. Metrices evaluate the 2D to 3D conversion techniques. The result demonstrate that, 3D brain model constructed using k means clustering and marching cubes algorithm provides the better result, because its accuracy, sensitivity, specificity, precision and fscore is high. Volumetric Overlap Error and Relative Volume Difference is low.

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