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An Efficient Approach for Converting 2D Medical Images Into Non Immersive VR Model

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Abstract— The primary objective of this paper is to find out an efficient approach for converting 2D medical images into a desktop level VR model. The target is achieved in three stages: segmentation, 2D to 3D reconstruction, and 3D to VR modeling. Segmentation is the process of partitioning the digital image into sub parts or meaningful segments which help in segregating the cognitive information in the region of interest. Several segmentation algorithms are used to segment the input image. Best segmentation techniques are preferred for 3D reconstruction. Two types of 3d reconstruction techniques are used in formulating a 3D model. The AMILab 3.2.0 is used to provide non immersive visualization. Quantitative metrics such as Accuracy, Sensitivity, Specificity, Precision, F Score, Border Error, Jaccard Distance, Volumetric Overlap Error, Relative Volume Difference, Average Symmetric surface Distance and Maximum Symmetric surface Distance are used to evaluate the performance. Constructed VR model helps students in learning human anatomy efficiently.

Keywords— Medical Image, Segmentation, 3D Reconstruction, Non Immersive VR.

I. Introduction

Technology plays a vital role in the progression of medicinal industry. The work of doctors and radiologist has been improvised by incorporating technologies such as Computer Aided Diagnosing (CAD), Virtual, Augmented and Mixed Reality. This provide extensive information regarding human anatomy by making them visualizing the organs in an imperative manner, practice the surgical procedures, help to assist doctors in diagnosing the diseases at an early stage, provide treatment planning and reduce mortality ratio. The medical images are the backbone for CAD. There are several types of medical images available some are, Magnetic Resonance Imaging (MRI), Computed Tomography (CT), Positron Emission Tomography (PET) and x ray. To provide advanced visualization Windows on World (WoW), Augmented Reality (AR), Virtual Reality (VR) and Mixed Reality are used. The term immersive is utilized to exemplify the present of an individual in the virtually constructed environment. WoW provides desktop level immersion, Augmented Reality provides partial immersion and VR provides complete immersion. To visualize the medical images in WoW, AR and VR, the following phases should be accomplished; they are pre processing, segmentation, 2D to 3D construction and 3D to virtual world conversion. There are various pre processing steps can be carried out in medical images such as denoising, enhancement, geometric transformations such as translation, rotation and scaling, interested area extraction, skull stripping etc. segmentation is the procedure of drawing out the image component.

II. Related Work

Different segmentation techniques are proposed till date such as adaptive threshold, region growing, region splitting, Otsu Threshold, K Means [1], Fuzzy C Means [2], watershed [3], Distance Regularized Level Set Evaluation (DRLSE) [4], Level Set, Chan Vese [5], Neural Network based Segmentation techniques etc. Selection of pre processing and segmentation techniques solely depends upon the application. 3D reconstruction technique is applied to construct the 3D model from the segmented 2D images. Volume based and surface based 3D construction techniques are available such as marching cube [7][8][15], ray casting, volume 3D [9][10][11][15], etc. Numerous tools and software's will be used to provide immersion such as OSIRIX, 3D slicer, Apple AR kit, Vuforia, Wikitude, Kudan, MaxST, Google AR Core, Easy AR, AR Tool Kit etc. This research work is proposed, to diagnose the efficient way of constructing non immersive VR model. Seven segmentation techniques were scrutinized in this paper that are K Means, Fuzzy C Means, Chan Vese, Expectation Maximization [6], Seeded Region Growing, Distance Regularized Level Set Evaluation, and Watershed segmentation. The best segmentation technique is utilized in constructing 3D model. Marching Cube and Volume 3D techniques are used in formulating the 3D model. Then the best 3D model is selected by performance metrics and then that model in transported into a non immersive environment to provide detailed visualization. This paper is categorized as follows, section III contains methodology, section IV contains result & discussion, section V contains conclusion and final section contains references.

III. METHODOLOGY

The work is carried out in four phases that are loading the input image, segmentation, 2D to 3D construction and finally 3D to non immersive visualization.

A. *Input Image:* The brain MRI DICOM images are given as an input.

B. *Segmentation:* Seven segmentation algorithms are analysed here, that are K Means, Fuzzy C Means, Chan Vese, Expectation Maximization, Seeded Region Growing, Distance Regularized Level Set Evaluation, and Watershed segmentation.

1. K Means Segmentation (KM):
It is an unsupervised algorithm. It starts with selecting k number of centroids randomly. Euclidean Distance amidst each centroids and pixels will be calculated, based upon that clusters are formed. Re initialize the centroids again, repeat the steps until no change in cluster formation. Formula to discover Euclidean distance is,

$$\sum_{i=1}^{k} \sum_{x_j} \left\| X_j - C_k \right\|^2 X_j \in k_i$$

Input image is represented by I, pixels as X={ x1, x2,…,xn}, clusters K= {k1, k2,…,kK },and centroids C={c1,c2,..ck}

2. Fuzzy C Means Segmentation (FCM):
It was proposed by J.C.Dunn in the year 1973. It is the advancement of classical algorithm. It incorporates the special concept called fuzzy. Fuzzy used to assign pixels to the appropriate cluster. When more than one clusters are nearer to the particular pixel, the ambiguity arise in assigning the clusters. Fuzzy make use of the degree of membership function, that accurately depicts which cluster, is more appropriately suited for that particular pixel. Input image is represented by I, pixels as X={ x1, x2,…,xn}, clusters K= {k1, k2,…,kK },and centroids C={c1,c2,..ck}.

Formula used to weigh the degree of membership function is μ_{ij} is,

$$\mu_{ij} = \frac{1}{\sum_{m=1}^{c} \frac{d_{ij}}{d_{im}\left(\frac{2}{k-1}\right)}}$$

3. Chan Vese Segmentation (CV):
The segmentation algorithm is based upon the mumford shah technique, it is an energy minimization algorithm with an unsupervised technique. The regularization term is derived using the length and area of the contour C. The energy minimization function is evaluated by using the following formula,

$$F(c_1, c_2, C) = \mu.Length\,(c) + v.Area\left(inside\,(C)\right) + \lambda_1 \int_{inside(c)} |\mu_0(x,y) - c_1|^2 dxdy + \lambda_2 \int_{outside\,(c)} |\mu_0(x,y) - c_2|^2 dxdy$$

$\mu_0(x, y)$ is an input image. c1, c2 represents the mean of pixel intensities inside and outside the contour C. μ, v, λ1 and λ2 are constants.

4. Expectation Maximization (EM):
It is an unsupervised and iterative clustering algorithm built upon the idea of K means clustering. .Initially pixel assigns to cluster with random probability. The mean (μ) and standard deviation (σ) of each cluster is derived, and then probably likelihood is calculated. Finally the pixels are assigned to cluster with maximum probability. The iteration stops when expectation likelihood merges with maximization step. The Gaussian probability function (*P*) for each pixel *x* is computed by,

$$P(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\frac{-(x-\mu)^2}{2\sigma^2}}$$

5. Seeded Region Growing (SRG):
Algorithm starts with selecting seed points, and the seed point is compared with the adjacent pixels. If they share the common properties, then it will be added with the seed pixel else the pixel will be neglected. Similar types of pixels are formed in a cluster. Repeat the procedure until all pixels are examined. Selection of seed pixel may be manual, automatic or semi automatic.

6. Distance Regularized Level Set Evaluation (DRLSE):
This is the up gradation of traditional level set algorithm. Energy or entropy, regularization term and potential function are used here. Level Set Function (φ) is defined upon the domain **Ω**. Energy function E(φ) is evaluated by,

$$E(\phi) = \mu R_p(\varphi) + E_{ext}(\varphi)$$

$$R_p(\varphi) \triangleq \int_{\Omega} P(|\nabla\varphi|)dx$$

Where $R_p(\varphi)$ is the distance regularization term, μ is a constant, $E_{ext}(\varphi)$ is the external energy over the curve and *P* is the potential function.

7. Watershed Segmentation (WS):
It translates the image into topographic view. The darker intensity pixels are portrayed by mountains and lighter intensity pixels are portrayed by valleys. Three terms used in segmentation procedure: regional minima, catchment basin of regional minima and divide lines. The algorithm begins filling water in each regional minima, and water continues rise in each catchment basin, at some instance water fills and starts to merge with nearest catchment basin. At that stage stop the water filling procedure and

start constructing dams to avoid water merging. Procedure will be terminated when all catchment basins are surrounded by dams. Markers are used to reduce the over segmentation.

C. 2D to 3D Reconstruction:

1. Volume 3D:

Volume 3D function used 2D orthogonal plane texture mapping technique for rendering. It makes use of the fast open GL hardware. The pre processing step which is carried out before 3D reconstruction is conversion of every slice to the same dimension and arranged all slice in the stack format. Each pixel in 2D is represented by x, y axis and the distance between the adjacent slice is denoted by Z axis. If there is pixel in one slice is adjacent to another pixel in the next slice, then these pixels will be linked together to form 3D model. Repeat the steps to cover all pixels in all the slices.

2. Marching Cubes:

The algorithm initiated with loading the series of input images. Scan the two adjacent slices at a time and construct a cube by incorporating eight pixels, four from each slice. Iso value is evaluated and each corner will be classified. If corner is above the iso value then cube is outside the boundary, if it is below then the cube is inside the object boundary, if some values are below and some are above then the cube is partially inside the boundary. Based upon that the 3D model is constructed

D. 3D to Non immersive VR:

To the conversion of 3D model into a non immersive VR world, a software named AMILab [13] [14] is used. It is developed for medical image processing, analysis and visualization. It supported several image processing algorithms; such as Gaussian convolution, non local means, 2D & 3D segmentation based on level set, image viewer, volume and surface viewer. It provides detail visualization by the help of adjusting opacity, azimuth, diffuse, specular factors and horizontal & vertical cropping.

IV. Result and Discussion

The input of T1&T2 weighted brain MRI images are collected from Brain Web [12] repository, it is noise free 1mm thickness images. Each type with holds one hundred and eighty one slices of input images. The performance metrics Accuracy (ACC), Sensitivity (SENS), Specificity (SPEC), Precision (PREC), F Score (FS), Border Error (BE) and Jaccard Distance (JD) are used to evaluate the performance of segmentation algorithms. Volumetric Overlap Error (VOE), Relative Volume Difference (RVD), Average Symmetric surface Distance (ASD), Maximum Symmetric surface Distance (MSD) and Accuracy (ACC) metrics are used to evaluate the performance of 3D model. ‘A’ represents segmented image volume and ‘B’ represents the reference image volume, d is a distance, TP,TN,FP and FN are true positive, true negative, false positive and false negative.

$$ACC = \frac{\#(TP) + \#(TN)}{\#(TP) + \#(TN) + \#(FP) + \#(FN)}$$

$$SENS = \frac{\#(TP)}{\#(TP) + \#(FN)}$$

$$SPEC = \frac{\#(TN)}{\#(TN) + \#(FP)}$$

$$PREC = \frac{\#(TP)}{\#(TP) + \#(FP)}$$

$$FS = 2 * \frac{\#(Recall * Precision)}{\#(Recall + Precison)}$$

$$BE = \frac{\#(FP) + \#(FN)}{\#(TP) + \#(FN)}$$

$$JD(S1, S2) = 1 - \frac{S1 \cap S2}{S1 \cup S2}$$

$$VOE = \left(1 - \left(\frac{|A \cap B|}{|A \cup B|}\right)\right)$$

$$RVD = \left(\frac{|A| - |B|}{|B|}\right) \times 100$$

$$ASD = \frac{1}{|A| + |B|} \times \left(\sum_{x \in A} d(x, B) + \sum_{y \in B} d(y, A)\right)$$

$$MSD = \max\{d_H(A, B), d_H(B, A)\}$$

Figure 1 shows the result of seven segmentation algorithms. The performance analysis of seven segmentation algorithm is given in figure 2. To indicate the better performance ACC, SENS, SPEC, PRES, FS should hold greater values and BE, JD should contain lesser values. Accuracy is given preference over sensitivity, specificity and precision. Based upon performance metrics, the Figure 2 clearly states that DRLSE algorithm segments the images in a precise manner, because it’s ACC and FS value is higher than K means, Fuzzy C Means, Chan Vese, Expectation Maximization, seeded region growing and Watershed segmentation algorithm, at the same time the value of border error and jaccard distance of DRLSE algorithm is lesser than other segmentation algorithms. The DRLSE segmented images are utilized to construct a 3D model.

Two algorithms are used: marching cube and volume 3D. By incorporating two category of input images T1, T2 weighted and two 3D reconstruction algorithm, marching cube and volume 3D, four 3D models were developed. Performance metrics are used to assess the 3D models. To indicate good performance ACC should be high and VOE, RVD, ASD and MSD should be low. The evaluations are given in table 1.

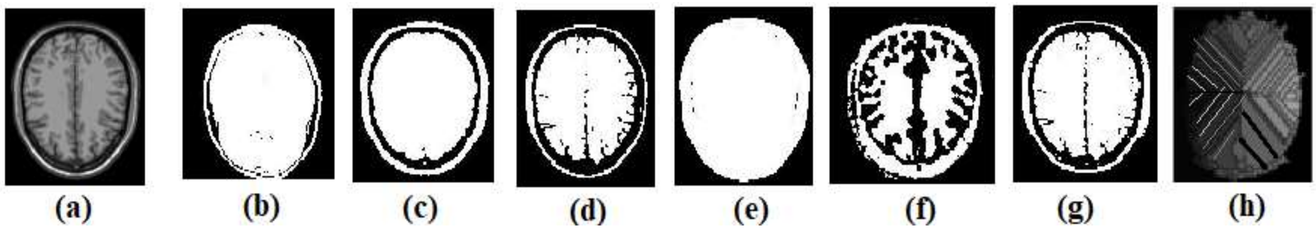

Fig 1: (a) T1 Weighted Brain MRI input image, (b) KM, (c) FCM, (d) CV, (e) EM, (f) SRG, (g) DRLSE, (h) WS segmentation algorithm

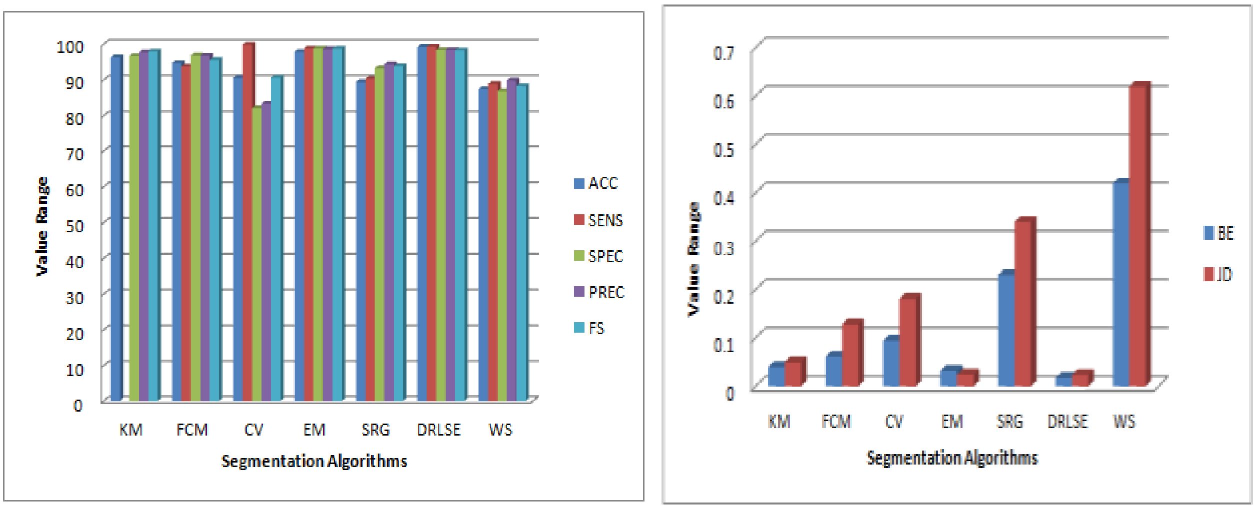

Fig 2: The comprehensive performance of segmentation algorithms over the metrics accuracy, sensitivity, specificity, precison, F Score, Border Error and Jaccard Distance for T1& T2 Weighted Images

Table 1: performance analysis of four 3D models formulated over the metrics ACC, VOE, RVD, ASD and MSD

Data Types	Algorithm	ACC	VOE	RVD	ASD	MSD
T1 WEIGHTED	DRLSE + VOLUME 3D	92.09	18.908	13.908	16.342	21.678
T1 WEIGHTED	**DRLSE + Marching Cube**	**94.92**	**16.562**	**11.425**	**14.345**	**18.435**
T2 WEIGHTED	DRLSE + VOLUME 3D	94.56	16.762	11.876	19.876	19.767
T2 WEIGHTED	**DRLSE + Marching Cube**	**97.65**	**14.233**	**9.098**	**16.789**	**15.456**

(a) (b)

Fig 3: (a) 3D model constructed using DRLSE segmentation and Volume 3D, (b) 3D model constructed using DRLSE segmentation and Marching Cube algorithm for T1 Weighted images.

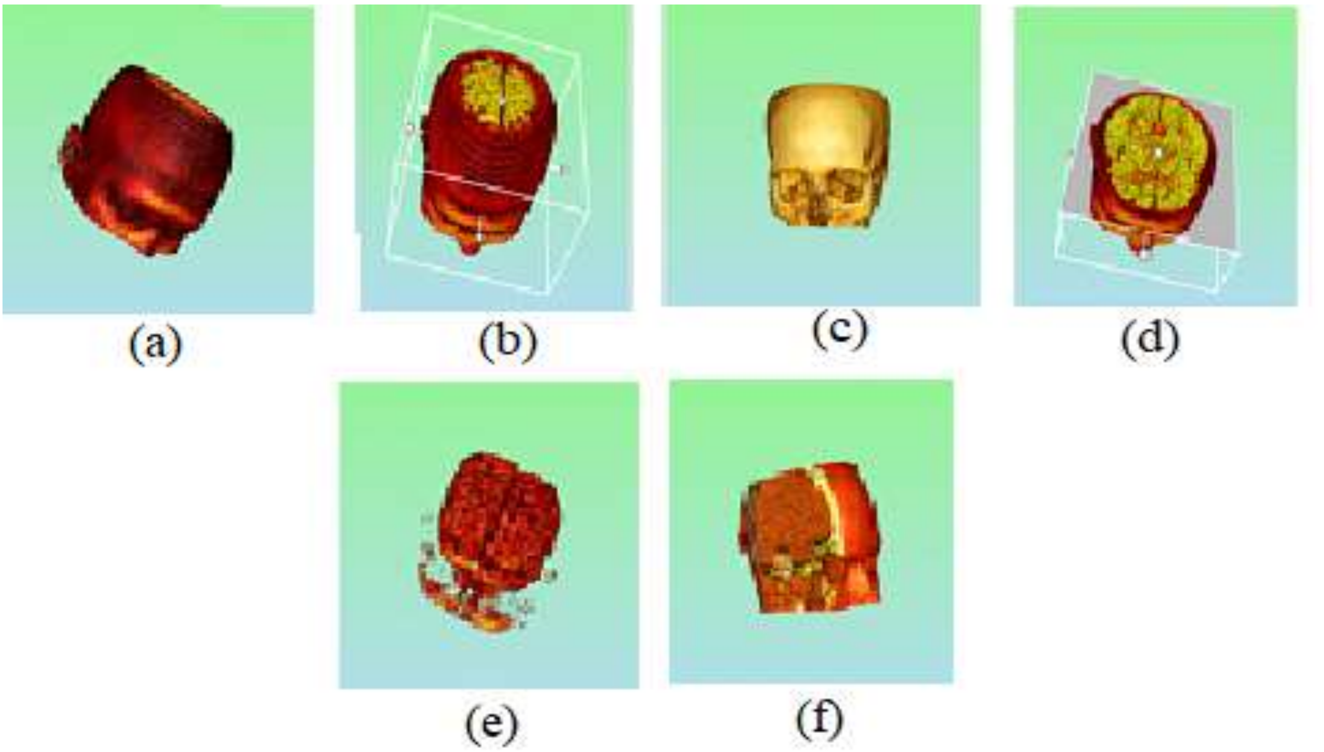

Fig 4: (a) Resultant 3D Human Head Model on non immersive environment, (b), (c) Adjusting Opacity Factor of Resultant 3D Model (d) Performance Of Crop Operation Over 3D Model (e)3D Model After Horizontal Cropping (f) 3D Model After Vertical Cropping

The table 1 states that the 3D models constructed using DRLSE and marching cube algorithm have higher ACC and lesser VOE, RVD, MSD and ASD for both T1 & T2 weighted images. Result states that 3D model constructed by incorporating DRLSE segmentation algorithm and marching cube 3D reconstruction algorithm, is more precise irrespective of data types. In next phase AMILab software is used to provide desktop level VR model. The non immersive visualization outcomes are shown in Figure 4, which includes resultant 3D head model, internal parts of head and horizontal and vertical cropping of the head at different perspective.

V. Conclusion

The T1 & T2 weighted brain MRI DICOM images are utilized for the investigation. Seven different segmentation techniques are applied over brain MRI images. They are K Means, Fuzzy C Means, Watershed, Expectation Maximization, Seeded Region Growing, Chan Vese and Distance Regularized Level Set Evaluation. The best segmentation algorithm is preferred for 3D reconstruction. The result of segmentation algorithm is concluded in qualitative and quantitative manner. The result states that DRLSE algorithms Accuracy, Sensitivity, Specificity, Precision and F Score is higher, Border Error and Jaccard Distance is lesser than the other algorithms.

Volume 3D and Marching Cube Algorithms are used, to construct the 3D model. The performance metrics are used in evaluating the 3D model. The result states that the 3D model constructed using DRLSE segmentation algorithm and marching cube algorithm is precise because it's accuracy is high (±96.285) and Volumetric Overlap Error (±15.3975), Relative Volume Difference (±10.261), Average Symmetric surface Distance (±15.567) and Maximum Symmetric surface Distance (±16.945) is low by comparing with other algorithms. The resultant best 3D model is used in AMILab software to provide non immersive detailed visualization. The result concludes that desktop level VR model constructed using DRLSE segmentation and marching cubes algorithm provides the better result.

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