

Software Proposal Document for Project BRAINYOLOGY

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Abstract

The main idea of the project is to study the MRI slices which will be the input to our system, then the system will calculate the volume of the tumor and reconstruct a 3D model for the whole brain and for the tumor using 2D input slices then the doctor will be able to interact with the visual 3D brain model using a dummy head. There will be a set of buttons in the dummy head that represents an important places in the brain if the button that refers to a specific part is pressed the system will highlight it this part in the brain 3D model and view set of outputs such as how far this area is affected by the tumor and what this area is responsible of in the human body.

1 Introduction

Brain tumor is collected of abnormal cells. Normally tumors are identified by CT and MRI. So conversion of 2D images to 3D images are taken place which has many issues like sharpen edges, color ambiguity, large displacement and zoom in zoom out which results in less accuracy of the image. Nowadays, 3D images gives effective results for identifying brain tumors, for this purpose we need to reconstruct 3D images from 2D images, which is a tedious process.

3D modeling have been involved in many applications such as:

(1) According to IEEE, 3D technology had been involved in modeling design graphics of environment art design teaching.

Yanan Zahang "The Application of Smart 3D Modeling for Design Graphics of Environment Art Design Teaching" in Measuring Technology and Mechatronics Automation (ICMTMA), IEEE, 2016,pp 1-6.

(2) Accuracy verification and enhancement 3d model.

G. Guidi "Accuracy verification and enhancement in 3D modeling: application to Donatello's Maddalena" in 3-D Digital Imaging and Modeling, IEEE, October 2003, pp 1-9

(3) According to IEEE, 3D technology had been used in modeling the brain of human body.

Ernesto Ponce "Modeling Neck and Brain Injuries in Infants", in IEEE Computer Graphics and Applications, 20 October 2011, pp 90-96.

2 Background

To make a 3D technology in your system, it needs a large amount of 3D content. However, it's both costly and time consuming to make a 3D content of high quality with stereoscopic cameras, so the shortage of 3D content become one of severe bottlenecks for 3D industry. In 3D modeling of brain using MRI images, we need to take a lot of slices from MRI images on the brain.

However, the images of MRI are 2D images which are not depict accurate the complexity of human anatomy in brain.[2]

Sudipta Roy "A useful approach towards 3D representation of brain abnormality from its 2D MRI slides with a volumetric exclamation" in Control and Information Technology (C3IT), IEEE, 8 Feb 2015, pp 1-6.[2]

3 Motivation

According to CancerIndex.org, People newly diagnosed with brain cancer are 108,600 and those who died in the last year from brain cancer were 72,300. Moreover, one of the biggest problem that faces

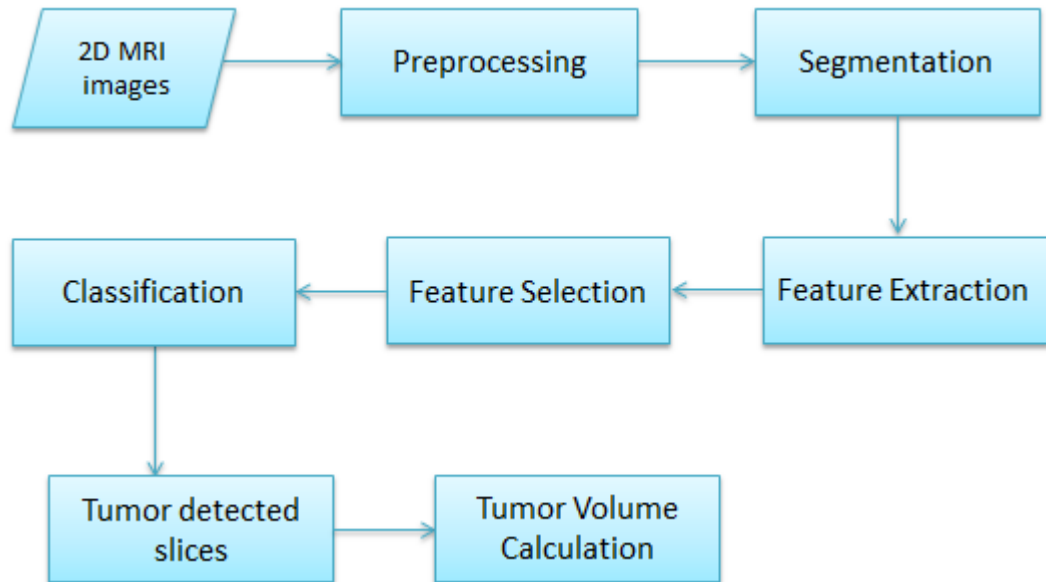
doctors is the calculation of the tumor volume through those 2D images. It's medically essential for the doctors to know the volume of the tumor, Knowing the accurate volume and the position of the tumor are key information doctors need to know which part of the patient body will be affected, Moreover will be able to plan treatment and they may predict the stage of the tumor.

4 Problem Definition

Brain tumors are identified by (CT) and (MRI) scans which are commonly used, those scan results in 2D images. The main problem that faces doctors is the calculation of the tumor volume through those 2D images. Here in Egypt there is one application that convert MRI 2D to 3D model which is applied on heart at Magdi Yacoub's heart foundation. But there is no application in Egypt for calculating the brain tumor volume and convert 2D MRI images of brain tumor to 3D model, The doctors also can't buy an application with the same functionality because it's very expensive, not accurate enough, the processing speed is very low and intuitive controller interactivity.

5 Project Description

Our project depends on MRI slices which will be the input to our system we will calculate the volume of the tumor and reconstruct a 3D model for the whole brain and for the tumor using 2D input slices then the doctor will be able to interact with the visual 3D brain model using a dummy head. There will be a set of buttons in the dummy head that represents an important places in the brain if the button that refers to a specific part is pressed the system will highlight it this part in the brain 3D model and view set of outputs such as how far this area is affected by the tumor and what this area is responsible of in the human body. The system is divided in to 3 modules. A. Image processing module



A.1 Preprocessing It is the initial process which uses 2D MRI images as input. The system converts 2D images to grayscale. The system uses high pass filtering for sharpening the edges and then contrast enhancement that attempts to improve the contrast in images. Finally, Threshold methods for separation of light and dark regions.

A.2 Segmentation It's a process of dividing an image into multiple segments which is achieved based on similar attribute. The goal of segmentation is to simplify or change the representation of an image. We have four techniques of segmentation which are Unseeded Region growing, OTSU'S thresholding, and Morphological Erosion and Connected component. We will practice the 4 techniques to achieve the most convenient one

A.3 Feature extraction It involves reducing the amount of resources needed to describe a huge set of data.

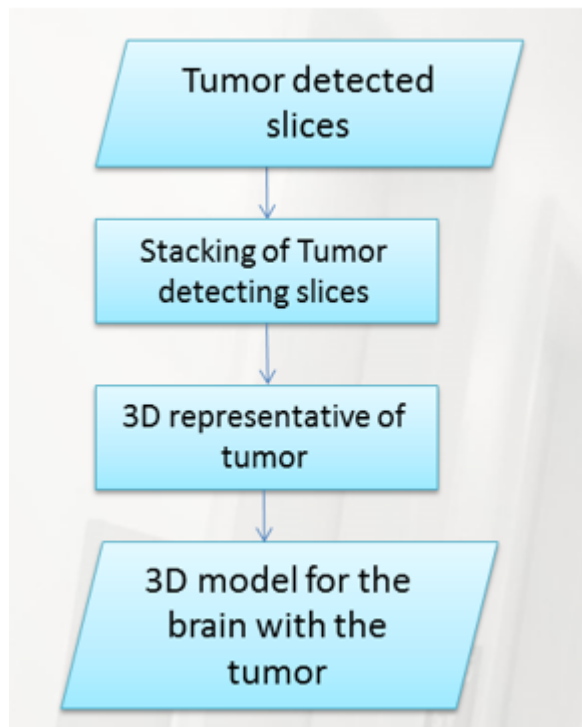
A.4 Feature Selection It's the process of selecting features which has been extracted from the last process. This process helps to reduce features by improving the prediction accuracy and reduce computation time.

A.5 Classification Is defined as a process in grouping the individual items based on similarity and description of those items, The aim of classification is to automatically categorize all pixels in an image into classes thereby Converting image data into information. Classification process involves training data set with known information and based of trained data each input pixel is assigned to particular class.

A.6 Tumor Detection Slices The MRI scan software system deliver collects all slices that contain tumor.

A.7 Tumor Volume Calculations. The system will calculate the volume of the tumor by taking binary images from tumor detection process as an input. System will use binary image as a matrix then the system will calculate the total volume of whole tumors in pixels using binary images and distance between two consecutive slices. If there are unknown slices the approach will use the concept of linear interpolation to find the area of the unknown slice by plotting obtained value in versus. slide number graph. Using this plot, the system can get the middle values of each unknown slide.

B. 3D reconstruction Module



The need of 3D construction from a series of 2D images, is to improve the understanding topology and the shape of the tumor, The 3D construction will be applied by stacking the slices of tumor on each other to form 3D matrix after that send the coordinates of

each pixel in the matrix to 3D mesh box.

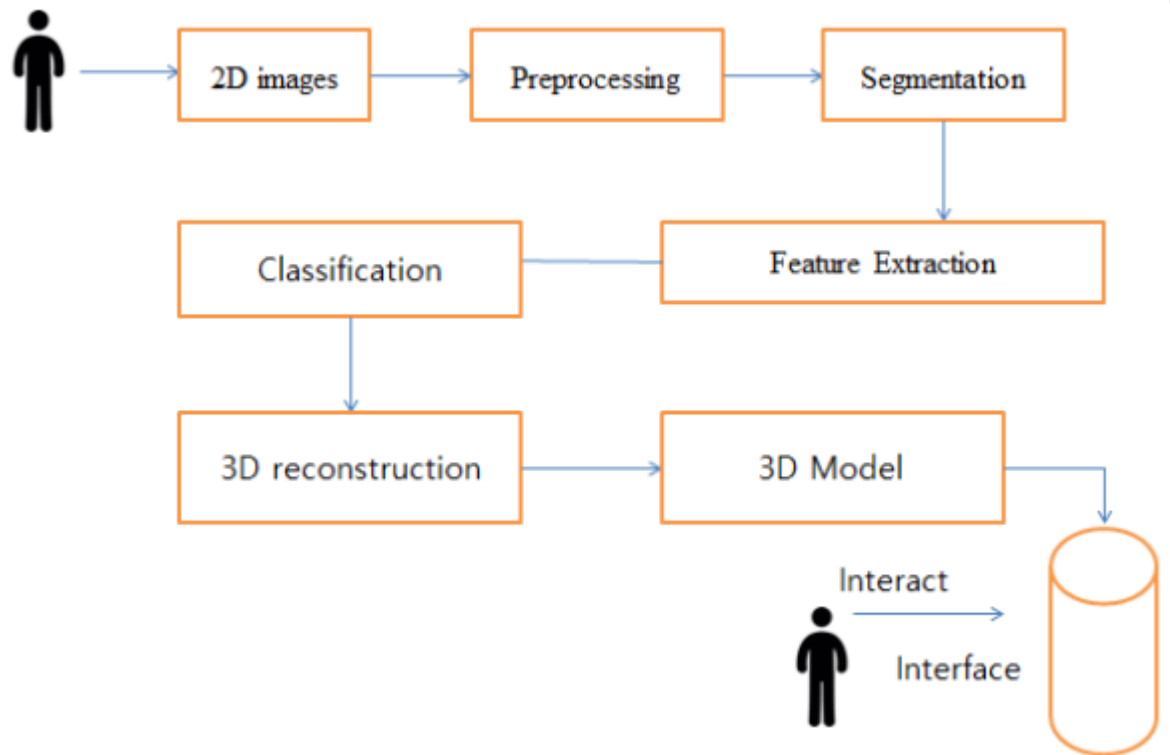
6 Objective

This system will be implemented to help doctors to give accurate diagnose to the brain tumor patient and by calculation of the volume doctors will be able to predict the degree of the tumor and if effect any part of the patient body or not. Consequently, the doctor will be able to better plan treatment for the patient. It also can be used for generating learning materials for the medical science or even surgical studies.

7 Scope

The system is targeting the adult male and female brain tumor patients. Our research scope is MRI images and Detect brain tumor only. We will be working on detecting the volume of the tumor. Our system will be integrated with many hospitals.

8 Project Overview



9 Similar Systems

1- Sudipta Roy, Shayak Sadhu, Samir kumar “Useful approach towards 3D representation of brain abnormality from its 2D MRI slides” in Control and Information technology (C3IT). IEEE, 7-8-2015, pp 1-6.

-They make this research to find the volume of the tumor inside the brain.

- Calculate the volume of the tumor inside the brain

-They used to kinds of methodology: 3D construction of brain, volume calculation from 3D constructed figure.

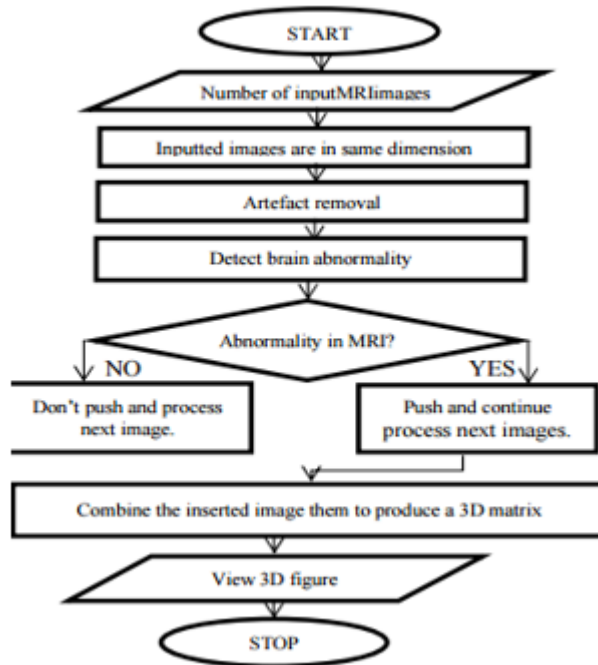


Figure 1: Overall steps of 3D visualization of brain abnormality.

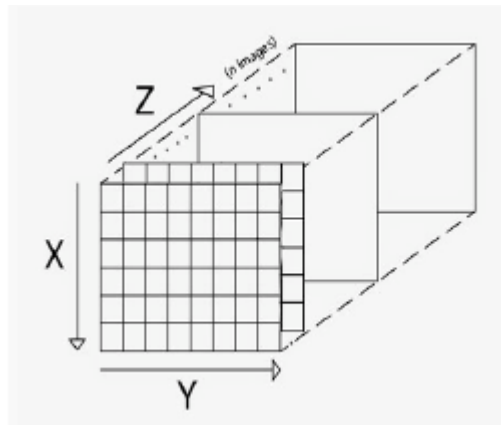


Figure 2: 2D matrices pushed into one another to form a stack

They used the concept of stack and its data structure. Here They consider each 2D matrix as stack and is pushed on top of each other to create a 3D matrix. A distinct separation is maintained between two image slides which denote the real-time separation when the slides were taken. The above explained method can be described by the figure They used mathematical equations to calculate the volume

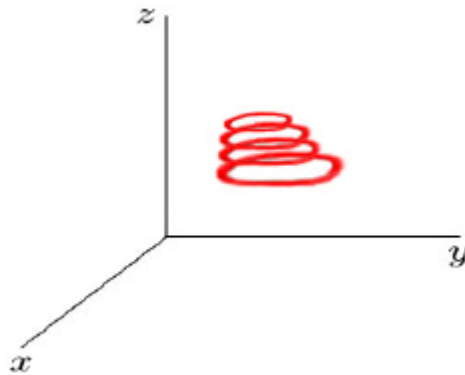


Figure 3: Graphical view the edges of each slide

After obtaining the above 3D matrix we 3D construct the above obtained matrix. In this process we consider the matrix as a 3D mesh box where each element in the matrix gives them the coordinate of each pixel in the box. Here they take the coordinates with 0's as the transparent part and the 1's as the solid part.

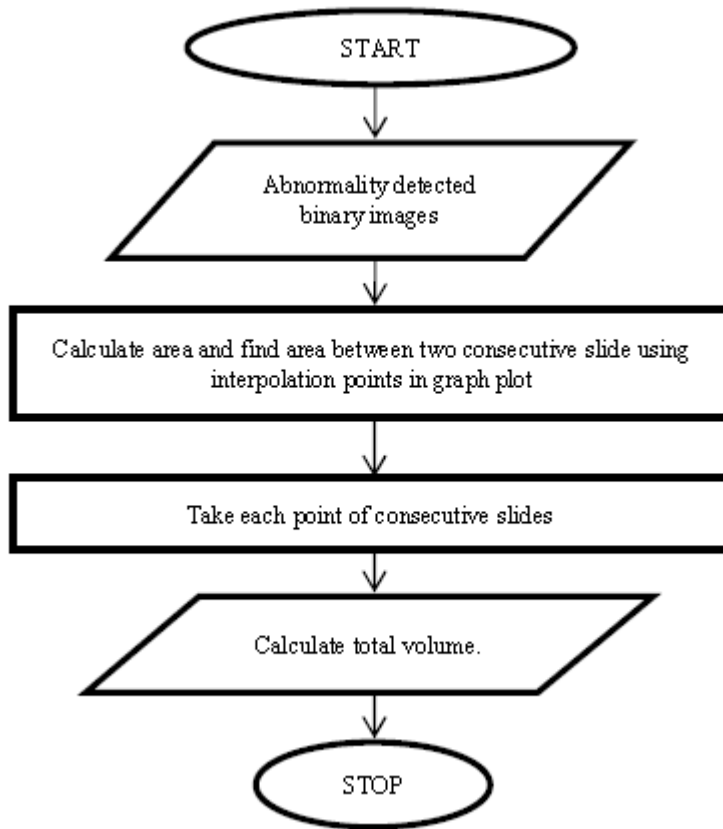


Figure 4: Steps of volume calculation

In this second part they calculate the volume of the tumour by taking binary images from tumour detection part from the previous stated algorithm as input. From the previous algorithm they get the binary image as the output of the tumour detection algorithm and using it as matrix they calculate the total volume of the whole tumour in pixels using the binary images and distance between two consecutive slides or slice thickness which must be taken from the user as it affects our calculation in estimation of volume. This image which can also be considered as a matrix is processed by the following algorithm to get our expected result. The flow diagram of this algorithm is given below in figure 3.

$$v = \sum_{m=1}^M \sum_{n=1}^N I[m, n] + \sum_{m=1}^M \sum_{n=1}^N I[m, n] + \sum_{m=1}^M \sum_{n=1}^N I[m, n] + \dots + \sum_{m=1}^M \sum_{n=1}^N Ix[m, n]$$

$$V = \sum_{k=1}^x \sum_{m=1}^M \sum_{n=1}^N Ik[m, n]$$

$$V = \sum_{k=1}^x x[k] \quad \text{where} \quad \sum_{m=1}^M \sum_{n=1}^N Ik[m, n] = x[k]$$

Equation 1

-The results that researchers reach, that they can detect the volume of the tumor inside the brain.

-This paper is very important for us, because it considered a part of our project idea.

2-Kavita A.Ugale, Prof. Dr. S.T. Patil “3D Reconstruction of Brain MRI using Support Vector Machine”, in International Journal of Advanced Research in Computer Science and Software Engineering, 7, July 2015, pp 1-5

-This paper covers 3-dimensional reconstructions of different encephalic tissues that determine irregularities and abnormalities in brain if there are any. Prior to reconstruction segmentation of MRI scan is done followed by classification using support vector machine. Segmentation is performed using two techniques region growing and dynamic Thresholds segmentation.

-In this paper the author want to use SVM classification after segmentation of MRI scan.

-In this paper the author does the task providing the seed point for threshold manually. This is a time consuming task. Thus the

execution time of the algorithm increases.

1-DATA PREPROCESSING:It is first step of proposed system, the brain MRI images which are taken as input, are subjected to be corrupted by noise during scanning. In this step we convert the original MRI image into gray scale image to reduce noise and to enhance the quality of image to get more accurate results. In proposed system Median filter is used to reduce the noise. The median filter is a non linear digital filtering technique, is often used to remove noise. Median filtering is very widely used in digital image processing because, under certain conditions, it preserves edges while removing noise. The median is a more robust average than the mean and so a single very unrepresentative pixel in a neighborhood will not affect the median value significantly. Since the median value must actually be the value of one of the pixels in the neighborhood, the median filter does not create new unrealistic pixel values when the filter straddles an edge. For this reason the median filter is much better at preserving sharp edges than the mean filter.

2-SEGMENTATION:Image segmentation is a process of subdividing an image into its constituent parts or objects in the image. The main motive of subdividing an image into its constituent objects is that we can further analyze each of these objects or our region of interest in the image once they are identified or we have subdivided them. So, each of this constituents can be analyzed to extract some information so that those information are useful for high level machine vision applications. Generally the level of segmentation is application dependent. There are two approached on which segmentation of an image is carried out.

A) Region Growing Segmentation:Region growing segmentation is the procedure which groups the pixels or sub-regions into a larger region based on some predefined criterion. Region growing works on principal of homogeneity. The main objective is to produce homogeneous regions. Algorithms assume that region must be connected with some predefined criteria. A seed point is collected or selected based n user criterion (pixel in certain gray scale ranges). Regions are then grown from seed point to adjacent points depending on region membership criteria for example pixel intensity. Algorithm start from single pixel(also called seed point)and try to find other pixels. Every pixel is compared with its neighbor for similarity check Such as gray level, texture, color, shape. If the result is positive, then that particular pixel is “added” to the pixel set and a region is “grow ” in

this manner. The growing is stopped when the similarity test fails. In proposed system region growing segmentation segment given MRI into constituent tissues.

B) Dynamic threshold segmentation:One of the simplest approaches to segment an image is based on the intensity levels and is called as threshold based approach. Threshold based techniques classifies the image into two classes and works on the postulate that pixels belonging to certain range of intensity values represents one class and the rest of the pixels in the image represents the other class. Thresholds can be implemented either globally or locally. Global Threshold discriminates object and background pixels by comparing with threshold value chosen and use binary partition to segment the image. The pixels that pass the threshold test are considered as object pixel and are assigned the binary value 1 and other pixels are assigned binary value 0 and treated as background pixels. The threshold based segmentation techniques are inexpensive, computationally fast and can be used in real time applications with aid of specialized hardware. Here, in dynamic Thresholding segmentation threshold value is set dynamically based on prior manual training.

3-FEATURE EXTRACTION:There is no explicit rationale of what constitutes a feature, and it often depends on the problem or the type of application. Feature extraction involves reducing the amount of resources needed to describe a huge set of data. The features used for the proposed system are: energy, homogeneity, correlation and contrast etc have been used.

4-CLASSIFICATION AND 3D RECONSTRUCTION:The next module is classification using support vector machine. The aim of classification is to automatically categorize all pixels in an image into classes thereby Converting image data into information. Classification process involves training dataset with known information and based of trained data each input pixel is assigned to particular class. SVM is one of the excellent tools for classification and regression problems with a good generalization performance. SVM formulates a hyper plain or a set of hyper plains to partition the two sets of data in a feature space. The key approach of SVM is to try finding the choicest hyper plain by maximizing the minimum margin between the two sets. Multiclass Support vector machine is used for classification in proposed system. Pixels are classified into classes of different encephalic tissues. radial basis kernel function is used. 3D reconstruction is process of capturing the shape and appearance of real

object. In proposed system reconstruction of 2D MRI slices. First step in reconstruction is, three dimensional stack from two dimensional MRI slices was prepared. Prearranged pixels are constructed based on observed neighborhood pixels are arranged based on smooth gradient

-They use two different types of segmentation of MRI scene region growing segmentation and Thresholds segmentation followed by classification using support vector machine.

-They proved that using SVM classification after region growing segmentation gives 3d model of brain with accuracy 93 percent.

-After they proved that using SVM classification after region growing segmentation gives 3d model of brain with accuracy 93 percent,I decided to use SVM classification as it gives 3D model of brain with the highest accuracy.

3- M.Fathima Zahira¹ and M.Mohamed Sathik “AN EFFECTIVE ANALYSIS OF MRI BRAIN IMAGES AND 3D RECONSTRUCTION”, in International Journal of Advanced Research in Biology, Ecology, Science and Technology (IJARBEST), February 2016, pp1-16.

-3D images are used for identifying brain tumors. Several techniques such as marching cubes and dividing cubes formed a topological relationship for the slices that converts 2D images into 3D images which does not provide accurate results and they depends on number of input sections, positions and the shape of the images. These processes take more time consuming for running and their tasks are very tedious

-In the paper they proposed a system introduces a 3D reconstruction for analyzing the MRI brain efficiently.

They used some image processing techniques:

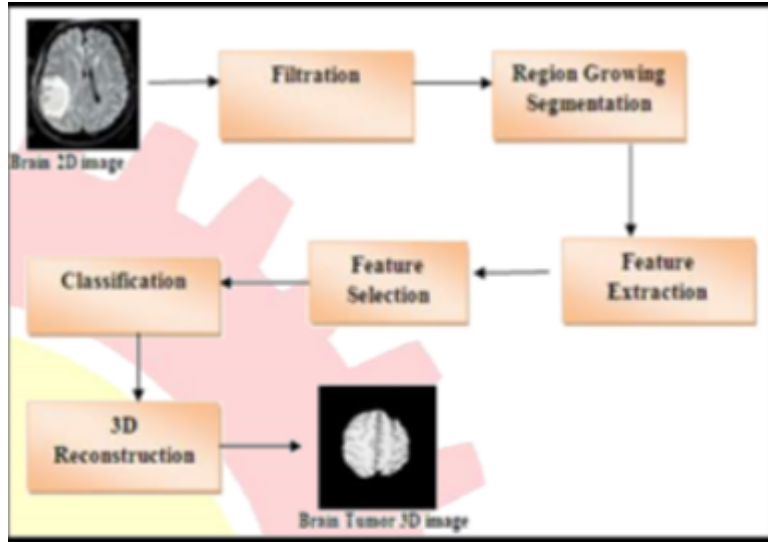


Figure 5: Steps of reconstruct 3D model

1.Filtration:Filtration is the initial process of the proposed approach which uses 2D images as input. The use Modified Spatial Median Filter for the removal of noise from 2D images. This filter uses the windows size (Mask) and threshold T for removing the noise. The spatial depths between each point are computes within the mask. They dicide the centered point in the mask are corrupted are not, if is not corrupted it will change. It identifies spatial depths of each point in the images. The spatial depth is determined by

$$S=(X,x1)=1-\frac{1}{(N-1)}\sum_{l=1}^N\frac{(X-x1)}{||X-X1||}$$

Equation 2

2.Segmentation:The goal of segmentation is to simplify or change the representation of an image that must be meaningful and it is analyzed easily which are further utilized. The brain image segmentation is the challenging task for all researchers.They proposed process focus on unseeded region growing segmentation which is follows: ●Segmentation process is initialized with the single pixel region called A1 which results in multiple regions such as (A1, A2, A3....An). Here B is set of all unallocated pixels which borders at least one region,

$$B = \{X \in \cup A_i \cap k : N(x) \cap A_k\} \text{ Equation 3}$$

Where $N(x)$ are immediate neighboring points of point x .

- Then calculate the difference on those test pixels with mean value of region statistics which decide the allocated and unallocated pixels. $g(x)$ denotes the image value at the point x , I is an index region where $N(x)$ intersects A_i .

- If difference is less, then the pixel is allocated at specific region.

- If condition not satisfied, then the pixel moved to new region A .

- If both the above conditions fails then the pixel are moved to a new region.

3. Feature extraction: The author used WVGLCM mechanism for the feature extraction process. This includes combined process of both GLCM and Wavelet process which results in effective results. They extract many features based on gray level concurrence matrices which can be computed for several distance and orientation. They used two components such as: Texture database and Texture recognition function. Texture database contains mainly two types of tables, which are texture name, texture type and glcm feature vector for the GLCM Texture database and Wavelet Texture database contains texture name, texture type and 2D wavelet feature vector. This process first performs the wavelet process and it is followed by GLCM Process. In wavelet process, The DWT decomposition [18] of image is performed to 5th level which is the end. Energy of each level, for each sub band (High-High, High-Low, Low-High, Low-Low) is calculated.

Feature Extraction Process

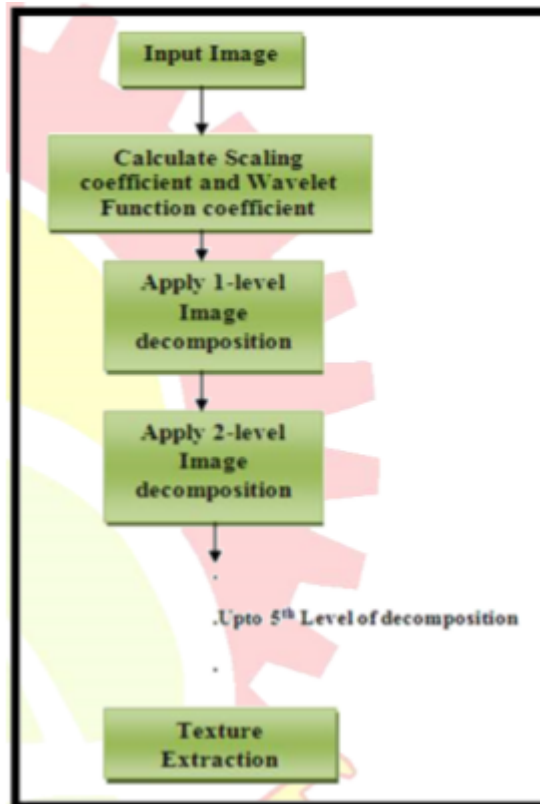


Figure 6: Feature Extraction Process

- Angular Second Momentum(Homogeneity)

$$ASM = \sum_{i=0}^{G-1} \sum_{j=0}^{G-1} \{P(i, j)\}^2 \quad \text{Equation 3}$$

- Contrast

$$\text{Contrast} = \sum_{n=0}^{G-1} n^2 \{ \sum_{i=1}^G \sum_{j=1}^G P(i, j), |i - j| = n \} \quad \text{Equation 4}$$

- Inverse Difference Moment

$$IDM = \sum_{i=0}^{G-1} \sum_{j=0}^{G-1} \frac{1}{1 + (i-j)^2} P(i, j) \quad \text{Equation 5}$$

- Entropy

$$\text{Entropy} = - \sum_{i=0}^{G-1} \sum_{j=0}^{G-1} P(i, j) * \log(P(i, j)) \quad \text{Equation 6}$$

•Correlation

$$\text{Correlation} = \frac{\sum_{i=0}^{G-1} \sum_{j=0}^{G-1} (i+j)P(i, j) - (\mu_x * \mu_y)}{\sigma_x * \sigma_y} \quad \text{Equation 7}$$

•Inertia

$$\text{Inertia} = \sum_{i=0}^{G-1} \sum_{j=0}^{G-1} (i - j)^2 * P(i, j) \quad \text{Equation 8}$$

•Variance

$$\text{Variance} = \sum_{i=0}^{G-1} \sum_{j=0}^{G-1} (i - \mu)^2 P(i, j) \quad \text{Equation 9}$$

4.Feature Selection: Feature selection is also called as attribute selection or variable selection in machine learning and statistics which is used for selecting the relevant features that used in model construction. This process is used for three reasons:

- Enhancement in generalization
- Reduced timing in training
- To simplify the models for researchers.

This process helps to reduce features by improving the prediction accuracy and reduce computation time. Our proposed process uses genetic algorithm to solve feature subset selection problem. Genetic Algorithm is excellent technique and it is combined with ANFIS (Adaptive neural network fuzzy inference system) which works as a filter for reducing the computation time.

$$\sum_{i=1}^{20} \frac{TP}{TP + FN} + \frac{TP}{TN + FP} + \frac{TN + TP}{TP + TN + FP + FN} \quad \text{Equation 10}$$

•True Positive (TP): Both training algorithm and testing algorithm results are positive

- True Negative (TN): Both training algorithm and testing algorithm results are negative.
- False Positive (FP): training algorithm result is positive and testing algorithm are negative.
- False Negative (FN): Training algorithm result is negative and Testing algorithm results are positive.

5. Classification: The Classification is defined as a process in grouping the individual items based on similarity and description of those items. In this paper, they used type-2 fuzzy logic system, it is an uncertain fuzzy rule based system which has imprecision in the input data and noisy measurement, non stationary feature uncertainty issues, etc.

$$\hat{A} = \{(x, u), \mu_{\tilde{A}}(x, u) | x \in X, u \in U, \mu_{\tilde{A}} \in [0, 1]\} \quad \text{Equation 11}$$

6. 3D reconstruction: The final stage of approach is that 3D reconstruction or modeling which is based on ImageJ tool. This tool can perform the process on images like display, edit and analyze. This supports image stacks, multiple images sharing single window and it is multithreaded, so it can perform parallel processing on multi-CPU hardware this leads to higher time consuming. This tool is integrated with public domain software, and also used for java based program. It was designed with an open architecture which provides for extensibility through recordable macros and java plugins. This tool is particularly flexible image-processing package and it is capable of handling both grayscale and color images. This tool intended purpose is medical image processing.

7. Performance evaluation: In this section, they proposed process is evaluated. The Unseeded Region growing segmentation and type-2 fuzzy logic system is implemented using MATLAB and real data set can be used which is for improving the segmentation accuracy and classification accuracy. Brain tumor disease has two types they are Benign, Malignant. Our proposed process involves unseeded region growing segmentation and type-2 fuzzy classification systems are most important work for analyzing MRI brain efficiently. In the paper they make a comparison with other classification methods such as SVM, Statistical Classifier, and Hyperbolic Hopfield Neural Network (HHNN). This will provide efficient results of brain tumor.

Table 1 compares between Segmentation Techniques which are K-mean clustering, OTSU'S Threshold , Watershed Algorithm and Unseeded region growing segmentation.

Segmentation Technique	Sensitivity	Specificity	Accuracy
K-mean Clustering Algorithm	84.5	84.5	84.3
OTSU's Thresholding	86.6	86.6	87.5
Watershed Algorithm	79.1	79.1	78.1
Unseeded Region Growing Segmentation	89.4	89.3	89.6

Figure 7: The represent of Table 1

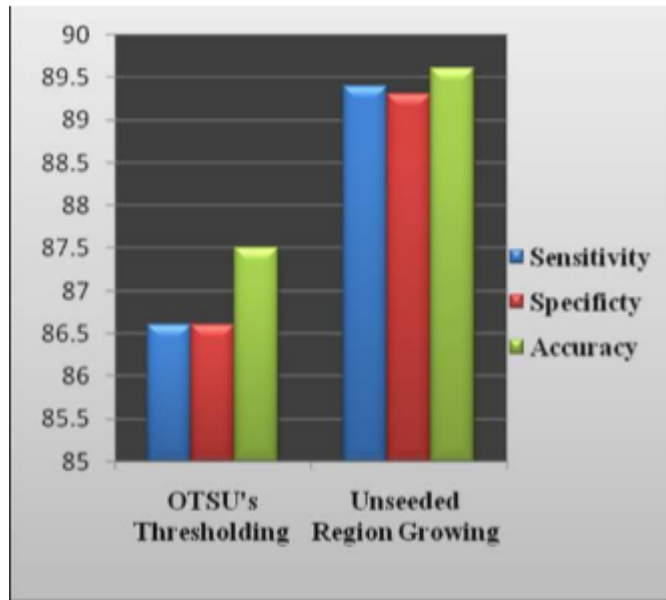


Figure 8: Graph representation of table 1

Table 2 compares between Classification methods and its accuracy which are SVM, Statistical Classifier, Hyperbolic Hopfield Neural Network and Type-2 Fuzzy logic System

Classification Methods	Accuracy
SVM	97.8
Statistical Classifier	88.2
Hyperbolic Hopfield Neural Network (HHNN)	98
Type-2 Fuzzy Logic System	98.4

Figure 9: The representation of Table 2

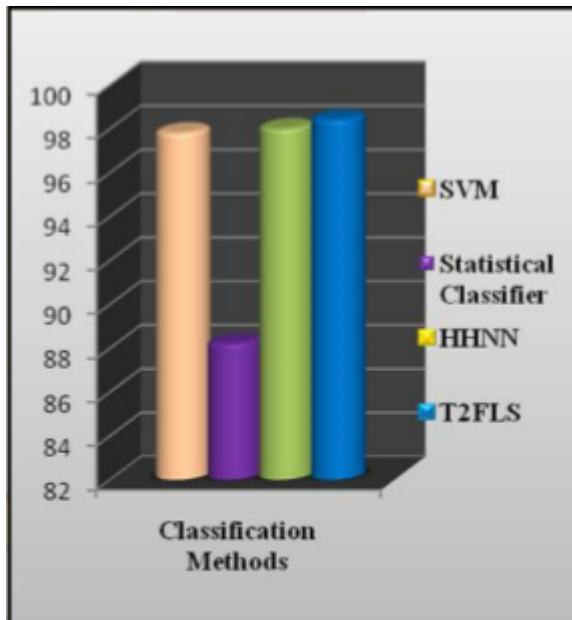


Figure 10: Graph representation of table 2

10 Table of Comparison

Technique	System 1 [1]	System 2 [2]	System 3 [3]
Segmentation	Unseeded region growing segmentation	Unseeded growing segmentation	<u>Thresholding</u> segmentation
Classification	Fuzzy Logic classification	SVM	SVM
Accuracy	89%	93%	89%

In our proposed system first we will try using the algorithms with the

-highest accuracy -Unseeded region growing segmentation -SVM

-The researches indicate that the images have to pass through

six stages such as preprocessing, region growing segmentation, feature extraction, feature selection, classification and 3D reconstruction, and they compared between the accuracy of the algorithms.

-This paper give as a huge feedback about which is the best algorithms we should use in our system.

References

[1]Yanan Zahang "The Application of Smart 3D Modeling for Design Graphics of Environment Art Design Teaching" in Measuring Technology and Mechatronics Automation (ICMTMA), IEEE, 2016,pp 1-6.

[2]G. Guidi "Accuracy verification and enhancement in 3D modeling: application to Donatello's Maddalena" in 3-D Digital Imaging and Modeling, IEEE, October 2003, pp 1-9

[3]Ernesto Ponce "Modeling Neck and Brain Injuries in Infants", in IEEE Computer Graphics and Applications, 20 October 2011, pp 90-96.

[4]Sudipta Roy "A useful approach towards 3D representation of brain abnormality from its 2D MRI slides with a volumetric exclamation" in Control and Information Technology (C3IT), IEEE, 8 Feb 2015, pp 1-6.[2]