# Evaluation of Skull Stripping in Magnetic Resonance Imaging using K-mean Clustering

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## ABSTRACT

Image Segmentation is the area of image processing that has been identified as the key problem of medical image analysis and remains a popular and challenging area of research. The segmentation refers to the process of partitioning a digital image into multiple segments. The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries in images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain visual characteristics. In this Paper two types of approach for segmentation is done and compared. Firstly a brain MRI is taken and its noises are removed using filters and also by using wavelet denoising and after that the skull is stripped using the morphological operations like erosion, dilation. Then in the next approach the skull stripping using Brain Extraction tool (BET) and then applied K-means Clustering algorithm and then find out the % area segmented. Magnetic Resonance (MR) has become the main modality for brain imaging that facilitates safe, non-invasive assessment and monitoring of patients with neurodegenerative diseases.

Keywords: - Segmentation. Skull stripping, K-means clustering, Fuzzy C-means clustering.

## 1. INTRODUCTION

After MRI scan if Radiologist does not get proper image i.e. if image is blur or there is any kind noise in that image then skull stripping is not done properly, hence, it becomes very difficult for the radiologist to analyze that image. To solve this problem one of the solutions is to do scan again but it incurs extra cost for the patient. Hence, to solve this problem, proposed research work is one of the solutions which are fruitful to both patient and the Radiologist.

MRI(Magnet Resonance Image) is a scan used for a medical imaging procedure .In medical image processing medical images are corrupted by different types of noises & no proper techniques are there for skull stripping, segmentation and clustering in a single step. It is very important to obtain precise image to facilitate accurate observation for the given application. Removing of noise from medical image is now a very challenging issue in the field of medical image processing. Most well known methods are usually based on local static and different techniques have to be used to solve different problems. Example: Water shade Algorithm is used for skull stripping, For Brain Segmentation Deformable Surface method is used, and for noise removing anisotropic diffusion filtering is there.[12]

To solve the above problem, proposed a simple method which does noise reduction, morphological skull stripping, Brain segmentation and also Clustering. All these combined together will be beneficial both for Radiologist as well as patient.

### 1.1 Methodology

#### 1.1.1 Magnetic Resonance Imaging

Nuclear Magnetic Resonance Imaging is a non-invasive 3D-image acquisition technique, based on differences in induced magnetization in biological tissues in the presence of a magnetic field. MRI attempts to capture magnetic properties of the material, such as proton density and relaxation times T1 and T2. These intrinsic parameters differ from one tissue type to another and are therefore the source of contrast in the image. Different acquisition parameters pulse repetition time TR, pulse echo time TE allow the generation of diverse types of images, with different contrasts between tissues, for some types of acquisition, a forward model exists for estimating an acquired image given the tissue parameters. T1-weighted MR images are commonly acquired for investigating structural aspects of the brain as they have good contrast between different tissue classes such as cerebrospinal fluid (CSF), gray matter and white matter. For these reasons, many different skull-stripping techniques have been specifically designed for this type of images, and we follow this choice for the implementation of our method.[12]

#### 1.1.2 Noise Removal

Noise removal is mainly used for remove the noise from any image which is being processed. In MRI Before the segmentation of brain MRI is done, the main step is to eliminate unwanted noises, so for that we need to apply the denoising method and need to apply the low pass Gaussian filter for removing all unwanted noises. After this process all unwanted noise will get removed. De-noising is always a challenging problem in magnetic resonance imaging and important for clinical diagnosis and computerized analysis, such as tissue classification and segmentation. It is well known that the noise in magnetic resonance imaging has a Rician distribution. Unlike additive Gaussian noise, Rician noise is signal dependent, and separating signal from noise is a difficult task.[1]

### 1.1.3 Morphological Skull Stripping

Morphological operations are applied on brain MRI to strip the skull apart. For that fastly convert the grey scale image to binary then image erosion is to be done and then find out the largest connected area. Then after that image dilation is done and then map to the grey scale, since the processing is done on grey scale.[3]

### 1.1.4 Brain Extraction

The brain extraction is used to remove the skull from an image, leaving only the region occupied by actual brain tissue. It segments these by using the dark space between the skull and brain occupied by the CSF. This comes from the external program FSL's toolkit. It will only appear if FSL is installed. The goal of the first brain extraction process is to remove most of the skull/throat/neck without loosing any brain tissue. This extraction will not be extremely accurate and may include more skull than desired in order to keep all of the brain tissue. The remainder of the skull can be removed in the second brain extraction using the same process.[6]

### 1.1.5 Segmentation

Segmentation refers to the process of extracting features of interest from images. Regions of interest within an image will have certain characteristic properties like intensity or texture constant. And these characteristic properties will be significantly different in the neighborhood. An image can be sliced into multiple regions, providing a clear computer vision into localized regions. Brain MRI segmentation aims at extracting the brain tissues WM, GM and CSF from the MRI pictures.[14]

## 2. MR Machine Working Principle

### 2.1 Nuclear Magnetic Resonance Imaging

MRI Stands for Magnetic Resonance Imaging; once call Nuclear Magnetic Resonance Imaging. The "Nuclear" was dropped on about 15 years ago because of fears that people would think there was something radioactive involved, which there is not. It is a medical imaging technique used in radiology to visualize detailed internal structures. MRI is a way of getting pictures of various parts of your body without the use of x-rays, unlike regular x-rays pictures and CAT scans. A MRI scanner consists of a large and very strong magnet in which the patient lies. A radio wave antenna is used to send signals to the body and then receive signals back. These returning signals are converted into pictures by a computer attached to the scanner. Pictures of almost any part of your body can be obtained at almost any particular angle. These "radio wave signals" are actually a varying or changing magnetic field that is much weaker than the steady, strong magnetic field of the main magnet. In order to perform MRI. We first need a strong magnetic field. The field strength of the magnets used for MR is measured in units of Tesla. One (1) Tesla is equal to 10,000 Gauss.[6]

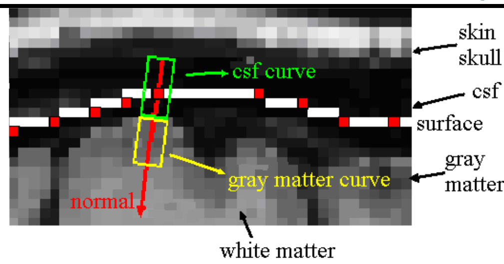
### 2.2 MRI Working Principles

MRI measures the density of hydrogen, which is abundantly present in the human body. It is a diamagnetic element with a significant magnetic moment, the reason to use H routinely. The patient is placed in a strong electromagnetic field of 0.3 to 3 tesla specialized MRIs up to 7 Tesla. The billions of H-atoms in the body align themselves parallel with the magnetic field, either in the same direction or opposite to the direction of the field. At the level slice, where it is desired to take a picture, a short and powerful radio signal is sent through the body, perpendicular to the main magnetic field. The H-atoms, which can vibrate with the same frequency as the impinging radio wave, will become excited, that is, they will be raised to a higher state of energy and start to resonate with the frequency of the exciting wave. When the radio signal is turned on, the hydrogen atoms will, after a period of time, return to their original energy state. The excitation energy, which they had gained, is now released in the form of radio waves, which are detected by sensors. The strength of this signal is proportional to the proton density (PD). The time it takes for the excited H-atoms to return to their original energy level, the relaxation time, is or can also be measured and analyzed by a computer. There are two types of emitted radio waves, with relaxation times T1 and T2. The former relies on the direct surrounding of the spinning proton and the latter on the mobility of the proton. One of the three can be used for the image, but a combination is also possible. For the contrast in the image and so for the interpretation of the image, information about what is used is needed To make an image one should also know where the emitted RF signal comes from, so one needs 3D-info. The RF coils (antennas) are not direction sensitive, so do not provide this information. The position is provided by the x, y and z gradient coils. CT may be enhanced by use of contrast agents containing elements of a higher atomic number than the surrounding water-like tissues. Contrast agents for MRI are those which are strongly paramagnetic. One example is gadolinium. Unlike CT, MRI has a long list of properties that may be used to generate image contrast. By variation of scanning parameters, tissue contrast can be altered and enhanced in various ways to detect different features. MRI can generate cross-sectional images in any plane including oblique planes. For purposes of tumor detection and identification, MRI is generally superior. However, CT usually is more widely available, faster, much less expensive, and may be less likely to require the person to be sedated or anesthetized.[13]

# 3 Existing techniques

## 3.1 The Watershed Algorithm

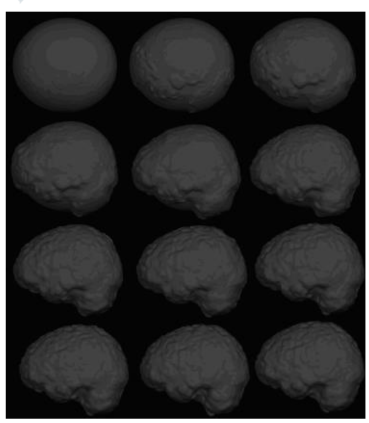
Watershed algorithms are based on image intensities. They usually try to locate the local maximums of the gradient intensity to segment the image into different connected components. The image intensity is often interpreted as height information: they use voxel values as heights in a landscape in which the brightest points correspond to the hills, and the darkest points represent the valleys. One of the main drawbacks of these techniques is that they often result in an over-segmentation, and appropriate merging criterions are required to post process the images. An interesting approach has been proposed by H.K. Hahn in which a solely intensity-based watershed algorithm is described: a simple merging criterion is defined to overcome the over-segmentation problem resulting in a fast and robust segmentation technique when quite uniform regions are targeted. Regarding brain anatomy, our basic assumption is the connectivity of the white matter. Since darker gray matter and even darker CSF surround the connected white matter, this region can be interpreted as the top of a hill.




They apply to the MRI image a watershed transform based on the concept of Pre flooding in order to avoid over-segmentation, a common problem in watershed techniques. We consider the inverted gray level in the T1-weighted brain image: under this transformation, the WM hill becomes a valley. Two points of the inverted image are connected if a path of adjacent voxels exists between them that are at least as dark as the brighter one of the two points. Under this strict definition of connectivity, the transformation would result in an over segmented brain. For that reason, we have to weaken our criterion for connectivity and utilize the concept of pre flooding. He does so by allowing the connectivity path to show a lower intensity than the darker of the two connected points up to a maximum difference the proceeding height.[17]

## 3.2 Deformable surface algorithm

In the Deformable Surface algorithm segmented volume may contain some non brain tissue such as CSF, or some parts of the skull. In some other infrequent cases, important parts of the brain may be removed, especially if the connectivity of the white matter is not preserved: the complete cerebellum may not be merged into the main basin, and be detached from the whole brain by the watershed segmentation. We first try to remove these extraneous parts, assuming that the watershed segmentation did not remove some important structures of the brain: we apply a deformable balloon-like template, with the segmented volume used as a mask. After the initial template deformation is completed, some global



Parameters regarding the brain/non brain border are computed. Finally, the template deformation resumes, accurately matching the boundary of the brain.[15]

## 3.3 Hybrid Method

Medical image are often deteriorated by noise during the production or reconstruction process. Image noise corrupts the image intensities and decreases the efficiency of segmentation algorithms. The pre-processing step consists of enhancing the MR brain slices to reduce noises. The image enhancement refers to sharpening of image features such as edges, boundaries or contrast to make the processed image more useful for analysis. Several methods have been developed and are widely used in the literature to denoised images. In the proposed method the brain slices are de-noised using mean filter. Mean filter is a simple, intuitive and easy to implement method of smoothing images. It reduces the amount of intensity variations between one pixel and the next. It is often used to reduce noise in images. In this method the input MR brain image slice is denoised using mean filter. The result of filtered image is blurred using circular averaging filter. The initial contour lines are drawn in the blurred image and it is further refined by hole filling and labeling to produce rough brain mask. Then it draws contour edges on the rough brain obtained from rough brain mask after performing morphological erosion operation. The proposed method output the final brain mask after applying hole filling and labeling in the final image contour.[4]

## 3.4 Mathematical Morphology

This method is a description and analysis of a morphological image-cleaning algorithm (the MIC algorithm). MIC was designed primarily to enhance scanned images and still-video images. The digitization processes introduce noise, which is usually of low amplitude but nevertheless can significantly degrade the appearance of the imagery. Moreover, the noise can reduce the efficiency of image compression schemes. Transform coding schemes (notably JPEG) can use quite a lot of storage space to code the noise in an image, that is, a noisy version of a clean image compresses to a larger size than the clean version. MIC removes image noise; this improves the subjective appearance of scanned and still-video imagery and improves the performance of JPEG compression. The goal of cleaning up images so that they look better to most people is admittedly subjective. Nevertheless, images that most people regard as clean possess two common characteristics: Edges, thin lines, and small features are sharp and clear. Areas between these features are smoothly varying. These two assumptions are fundamental to many image restoration techniques and image models. Hence, they are the goals of many such procedures, including MIC.[5]

# 4 Proposed Method

## 4.1 Method

This approach to the segmentation problem can be categorized as shown in following figure.

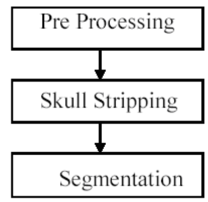



Figure 4.1: Processing of Segmentation Problem

## 4.2 Preprocessing

Preprocessing forms an important step in all image processing applications. The high frequency noise induced in the image can be effectively removed using filters. Different mask sizes can be used to implement low pass filters. We used low pass filter to remove any high frequency noise speckles present in the image. The raw MRI image is first passed through a Low Pass Filter to be used for segmentation.[16]

## 4.3 Skull Stripping

The MRI picture has both the skull and the brain tissues. To segment the brain, the brain tissues which are of interest need to be extracted from the original image. The surrounding skull tissues are removed from the MR Image to achieve this. This process of removing the skull tissues is termed as Skull Stripping. Many skull stripping methods are employed. The main feature of our algorithm is that we have exploited the anatomy of the brain to strip the skull and segment the tissues. Our algorithm becomes totally automatic as all the intensity values are automatically determined from the histogram.[18]

## 4.4 Segmentation

Segmentation refers to the process of extracting features of interest from images. Regions of interest within an image will have certain characteristic properties like intensity or texture constant. And these characteristic properties will be significantly different in the neighborhood. An image can be sliced into multiple regions, providing a clear computer vision into localized regions. Brain MRI segmentation aims at extracting the brain tissues WM, GM and CSF from the MRI pictures.[19]

## 4.5 Implementation of Proposed Method

4.5.1 Noise Removal

Before the segmentation of brain MRI is done, the main step is to eliminate unwanted noises for that purpose Mat lab for noise removal and smoothing the MR image. Further low pass Gaussian filter for removing all unwanted noises. In the other words after this process all unwanted noise will be removed.[5]

**Processing of image by MATLAB:**

**Step 1:** Start MATLAB.

**Step 2:** File -> New -> Mfile -> Write Program for filtering & Smoothing Image.

**Step 3:** Run program.

**Step 4:** Save the output image in particular folder.

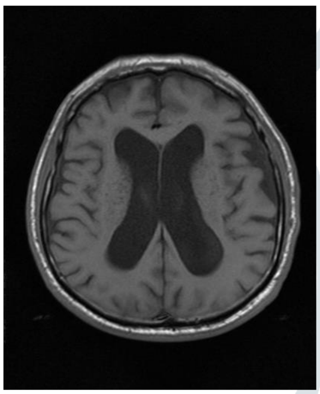


Figure 4.2: Input image to MATLAB

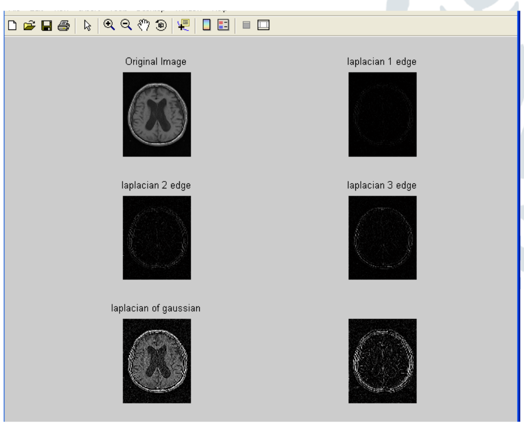
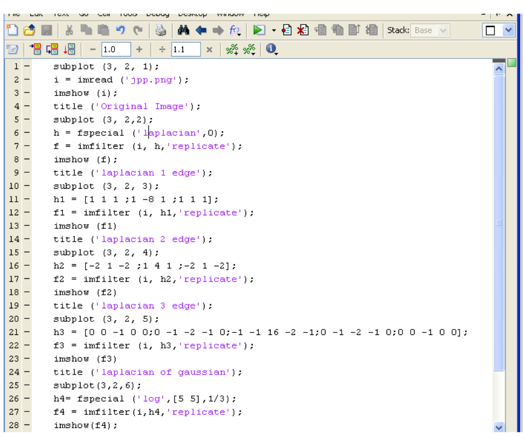



Figure 4.3: Output image to MATLAB



```
subplot (3, 2, 1);
i = imread ('jpp.png');
imshow (i);
title ('Original Image');
subplot (3, 2,2);
h = fspecial ('laplacian',0);
f = imfilter (i, h,'replicate');
imshow (f);
title ('laplacian 1 edge');
subplot (3, 2, 3);
h1 = [1 1 1 ;1 -8 1 ;1 1 1];
f1 = imfilter (i, h1,'replicate');
imshow (f1)
title ('laplacian 2 edge');
subplot (3, 2, 4);
h2 = [-2 1 -2 ;1 4 1 ;-2 1 -2];
f2 = imfilter (i, h2,'replicate');
imshow (f2)
title ('laplacian 3 edge');
subplot (3, 2, 5);
h3 = [0 0 -1 0 0;0 -1 -2 -1 0;-1 -1 16 -2 -1;0 -1 -2 -1 0;0 0 -1 0 0];
f3 = imfilter (i, h3,'replicate');
imshow (f3)
title ('laplacian of gaussian');
subplot(3,2,6);
h4= fspecial ('log',[5 5],1/3);
f4 = imfilter(i,h4,'replicate');
imshow(f4);
```

Figure 4.4: Code used to process image in MATLAB

4.5.2 Morphological Skull Stripping

After the removal of noises morphological operations are applied on brain MRI to strip the skull apart. For that firstly convert the grey scale image to binary then image erosion is to be done and then find out the largest connected area. Then after that image dilation is done and then map to the grey scale, since the processing is done on grey scale. In order to solve the problem, replace the step of boundaries detecting by threshold segmentation because the pixels in the part of background and CSF (cerebrospinal fluid) have lower gray values, while the others have higher gray values. The region between the skull and the brain tissue can be extracted by threshold. But this region is not always closed; so connect those discontinuous parts to make sure the brain region not connect with other tissues. The connected region is called ring in the following part which looks like a ring. In this regards at the beginning of this section some unwanted edges lead to the pits in the surface of template. And those unwanted edges always attach themselves with the closed ring. It is difficult to remove those unwanted edges directly. In order to remove those unwanted edges effectively, the process the ring using an algorithm of skeletonization. Because the skeletonization can preserve the region of the brain tissue. Meanwhile, the unwanted edges be simplified the burrs of the ring and then remove those burrs. The next step is to find the connected region which is same with above method.[11]

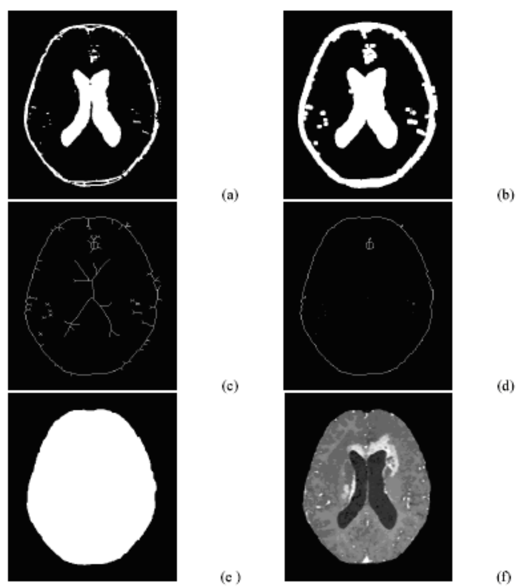



Figure 4.6: Morphological Skull Stripped Image

4.5.3 Segmentation of Brain

**4.5.3.1. Histogram Analysis:**

Once the brain tissues were extracted from the MR Image after skull stripping, segmentation of the brain tissue into three different classes of interest White Matter, Gray Matter and Cerebrospinal Fluid was carried out. That has made use of threshold application and seed region growing techniques. A 3D seed growing method looking for 26 adjacent pixels is developed. The method has used the global histogram of the picture to automatically segment the tissues. For choosing the seed values and applying the threshold limits from the histogram, the method has made use of the prior knowledge that the brightest region of the pixels in the skull stripped image represents WM and a predefined margin is fixed for GM from that of WM. This characteristic remains same from image to image though the pixel values might itself change. These values are detected for every slice from the histogram. Thus the human intervention is not called for in deciding the seed value.[14]

**4.5.3.2. Segmenting White Matter:**

Histogram regional maximum value was used for picking up pixels representing WM. A small offset was given to the regional maximum to decide the seed value for the WM. All the WM pixels were segmented using region growing choosing the four point neighborhood connectivity. First the pixels with the white matter seed value are set to 1 in a mask. Method define a pixel to be white matter if it has intensity greater than the seed value and is four points connected to any pixel whose corresponding pixel in the mask is set to 1. If the condition is satisfied, the pixel corresponding to this point in the mask is set to 1.This process is continued for a predefined number of iterations. After the WM mask is grown completely, the method used image arithmetic between the two images i.e. with the skull stripped image and the WM mask to extract WM.

**4.5.3.3. Segmenting Gray Matter:**

Segmentation in the previous step removes White Matter. This leaves the skull with Gray Matter and CSF. The Gray Matter pixels appear less bright than the White Matter pixels. The GM pixels are detected giving an offset from the WM intensity values. This method grows the mask for Gray pixels by setting pixels with the Gray Matter threshold value to 1 in the mask. Now, this method follows the same seed growing process looking for the four point neighborhood connectivity and extracts the GM. The mask developed for GM combined with the skull stripped and segmented WM is used to separate GM.

**4.5.3.4. Segmenting Cerebrospinal Fluid (CSF):**

After successfully segmenting the WM and GM and removing them from the skull stripped image, CSF is segmented from the skull stripped image without seed growing. Only image arithmetic is used to extract CSF

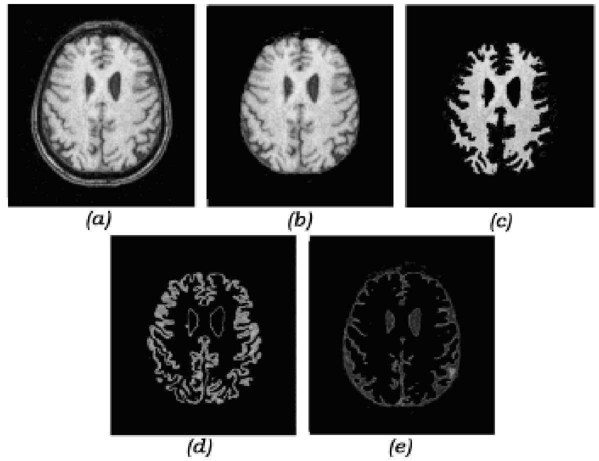



Figure 4.7: Segmentation of brain tissues from MR Image

The different stage in which segmentation is carried out is outlined in the following flowchart.

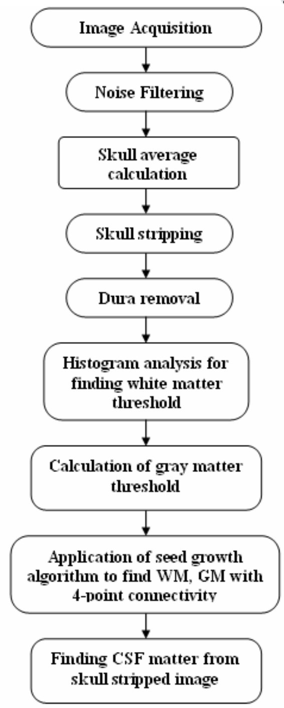



Figure 4.8: Detailed Flowchart

## 4.6 Steps of Proposed Method

Following is the proposed algorithm.

**Step 1.** Take an input Image from the MRI Machine.

**Step 2.** Use MATLAB tool for Noise Remove.

**Step 3.** Use Morphological Skull Stripping Method for Stripping the skull.

**Step 4.** Then we apply the segmentation method For Segment the Brain Part.

**Step 5.** Then we apply K- Mean Clustering Method to cluster the Brain Part.

**Step 6.** After this Process we will check output Image, If image is not proper then go to Step 2
Else go to Step 7

**Step 7.** Take output Image and gives to Radiologist.

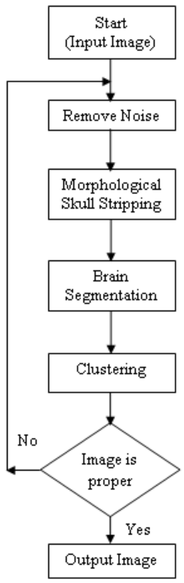



Figure 4.11: Proposed Flow Chart

# 5. Experimental Work and Results

## 5.1 Noise Removal

Used MATLAB tool to get the final image used MATLAB tool. In this tool, first inserted the blurred image or noisy image then applied filters to that image. After applying filters when run the tool, get the final image which is free from noise.

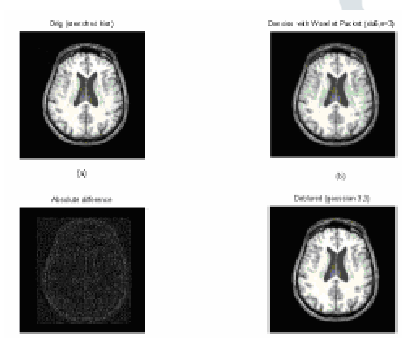


Figure 5.1: Noise Removal of brain MRI

## 5.2 Morphological Skull Stripping

For Morphological Skull Stripping, used following steps: Threshold processing, Link the gap, Skeletonization and deburring, fill holes and modify the image for getting stripped skull image.

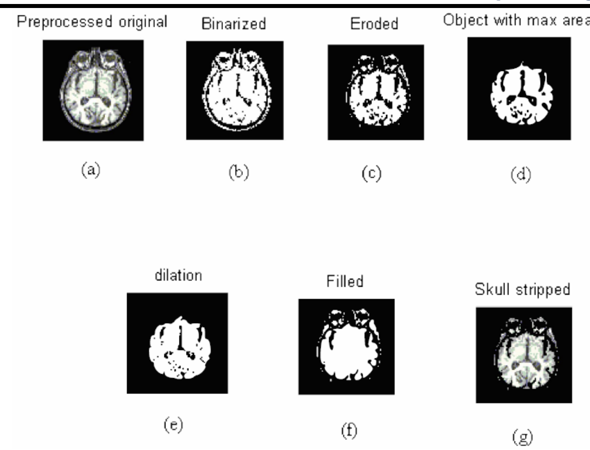



Figure 5.3: Skull stripping for figure 5.1

## 5.3 Segmentation

MATLAB tool is used for stripping or used BET, FEAT tool for segmentation of CSF, WM, and GM.

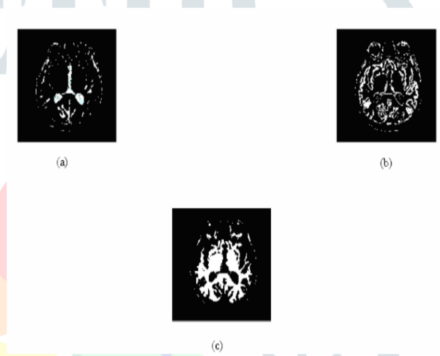


Figure 5.5: Segmented image for figure 5.3

## 5.4 Clustering

After getting the right images by performing the above steps then cluster them and get the final resultant image.

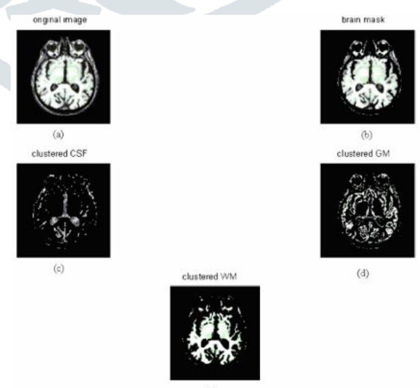



Figure 5.7: Clustered image for figure 5.5

# 6. Performance Evaluation

This is the Table for for finding the % area of Segmentation from Mean Squre Error and Peak Signal Noise Ratio.

| Experiment | MSE | PSNR | % Of Area Segmented |
|---|---|---|---|
| Exp 1 | 0.0146 | 72.5456 | 95% |

Resulting Graph: This is the resulting graph generated by using the above table.

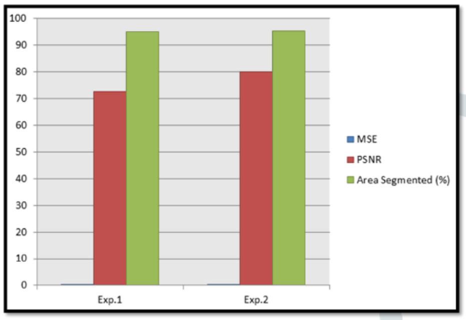



Figure 6.1: Resulting Graph

# 7 Conclusion

In this proposed method analyzed the MRI DICOM brain image such as axial, coronal, sagittal Tl-weighted, T2-weighted, and PO weighted. In this research method image denoising techniques and morphological Method is done and connected component labeling to perform non brain portion removal, after that applied Brain segmentation method for segmenting the brain part. After that weighted k-means clustering technique is done and applied skull stripping using manual method. Thus calculated the area of regions of segmented tissues, which is useful for the quantification of the data for the radiologists. According to the area, performance is evaluated and selected suitable clustering algorithm. Proposed Method is the most appropriate method using this approach.

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