A Comparison between ROI Extract and FCM Algorithms in Segmentation of Tumor Region from MR Brain Images

A.Almusthaliba*1,G.Vishnuvarthanana*2,S.Meenakshi*3

#PG student, Department of ICE,
Kalasalingam University, Tamil Nada, India

*Assistant Professor – I. Department of ICE
Kalasalingam University, Tamil Nada, India

*Assistant Professor, Department of EIE
Sethu Institute of Technology, Tamil Nada, India

Abstract— Segmentation of brain images based on Magnetic Resonance (MR) is used to segment and analyse the slices of brain to indicate the presence of tumour. Region of interest (ROI) extract is used to select the exact spot in an image where the tumour is present. Primary area of interest (tumour region) is chosen by the algorithm. The chosen region is completely extracted out from the input image. Fuzzy means algorithm is a soft clustering method in which the data elements (pixel values) are divided and clustered into two or more clusters. FCM is carried out by clustering the similar pixel values into one cluster and dissimilar pixel values into another cluster. A comparison is carried out between these two algorithms with the help of parameters such as Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR), segmentation accuracy, Jaccard index, computational time and memory requirement for processing the algorithm. The efficiency of either algorithm is proved using the comparison parameters.

Keywords— Magnetic resonance (MR) brain images, Region-of-interest (ROI) and Fuzzy C-means (FCM)

I. INTRODUCTION

Magnetic Resonance Imaging (MRI) provides clear images of living tissues and is used for both brain tissues and human body studies. Data obtained from MR images is used for detecting tissue deformities like cancer and injuries; MR is also mainly used in the studies of brain pathology, where Regions of Interest (ROI) are often examined in detail, for example in multiple sclerosis (MS) studies. In order to obtain good quantitative studies, ROI’s within the brain must be well described. In conventional methods, a skilled operator manually outlines the ROI’s with the use a mouse or cursor. Recently, computer-assisted methods have been used for specific tasks such as extraction of MS lesions from MRI brain scans, or extraction of the cerebral ventricles in schizophrenia studies. Many of these computer-assisted tasks require segmentation of the whole brain from the head, either because the whole brain is the ROI such as in Alzheimer’s studies or because automatic ROI extraction using statistical methods is made easier if the skull and scalp have been removed[1].

II. MAGNETIC RESONANCE IMAGING (MRI)

Imaging plays a central role in the diagnosis of brain tumors. Early imaging methods were invasive and sometimes dangerous such as pneumo-encephalography and cerebral angiography have been abandoned in recent times because of their non-invasiveness. High-resolution techniques especially Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) scans are preferred these days. There are various sequences in MR images like T1, T2, FLAIR and MRS. Among these, T1, T2 and FLAIR are widely used.

III. REGION OF INTEREST

The idea of an ROI is commonly used in many application areas. For example, in medical imaging, the borders of a tumor may be defined on an image or in a volume, to measure its size. The endocardial border may be defined on an image, maybe during different phases of the cardiac cycle, say end-systole and end-diastole, for the need of assessing cardiac function. In geographical information systems (GIS), an ROI can be taken actually as a polygonal selection from a 2D map. In the view of computer imaging system, the ROI defines the borders of an object under consideration. In many applications, symbolic (textual) names are added to a ROI, to describe its content in a compact manner.

An ROI can contain many numbers of individual points called Point of Interests (PoI)

An ROI is a form of elucidation, often associated with categorical or quantitative information (e.g., measurements like volume or mean intensity), displayed as text or in structured form.

There are three fundamentally different means of encoding an ROI:

- As a vital part of the sample data set, with a unique or masking value that may or may not be outside the normal range of normally occurring values and which tags individual data cells
- As separate, completely graphic information, such as with vector or bitmap (rasterized) drawing elements, perhaps with some accompanying plain (unstructured) text in the format of the data itself

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• As a separate structured semantic information (such as coded value types) with a set of spatial and/or temporal coordinates

A. Block diagram to identify tumor region

![Block Diagram to Identify Tumor Region](image)

IV. FUZZY C-MEANS (FCM) ALGORITHM

Fuzzy C-means (FCM) algorithm is a clustering technique developed by Dunn, improved by Bezdek and further improved by Matteo Matteucci; in this technique the voxels (data) of the Magnetic Resonance (MR) brain images are classified and grouped under ‘n’ number of clusters specified by PSO algorithm \( \hat{x}_i(t + 1) \), the updated position vector of the particle (Voxel or pixel) derived with the help of PSO algorithm acts as the Centroid value and based upon this value, the number of clusters for FCM algorithm is also assigned using PSO. Using the position vector, centre voxel of each cluster is identified and assigned with a high membership grade value through FCM. The neighboring voxels of least mean distance from the centroid voxel are assigned with low membership grade value and are grown around the centroid value, hierarchically. The membership grade and the cluster centers are iteratively updated to reduce the objective function of grouping the voxels.

\[
J_k = \sum_{i=1}^{N} \sum_{j=1}^{C} \delta_{ij} \| x_i - c_j \|^2
\]  

where \( x_i \) = Data points (voxels or pixels), \( \delta_{ij} \) = Degree of membership for the \( i^{th} \) data point of \( x_i \) in cluster \( j \).

\[
\| x_i - c_j \| = \text{Measuring the similarity or mean distance of the neighbouring voxels present in the data point } x_i \text{ to the centre vector (centroid value) of cluster } j.
\]

Degree of membership is given as, \( \delta_{ij} = \frac{1}{\sum_{k=1}^{C} \left( \frac{\| x_i - c_k \|}{\| \hat{x}_i(t) - c_k \|} \right)^p} \)

\( m = \text{Fuzziness co} – \text{efficient obtained from the overlapping of clusters and it is defined as } 1.5 \leq m \leq 2.5 \text{ for optimum segmentation results} [17]. \)

Centre vector (Centroid voxel) for the cluster is defined as, \( c_j = \frac{\sum_{i=1}^{N} \delta_{ij} \cdot x_i}{\sum_{i=1}^{N} \delta_{ij}} \)

During the initial processing of the algorithm, \( \delta_{ij} = \theta_{ij} \)

\( \theta_{ij} = \text{A random value initialized as, } 0 \leq \theta_{ij} \leq 1 \text{(Usually expressed as 0, 0.1, 0.2, 0.4,…1), such that} \sum_{j} \delta_{ij} = 1. \)

V. EVALUATION CRITERIA

Output obtained from the lesion segmentation based on the ROI method and FCM methods are compared with the gold standard. The similarity criteria (SI), overlap fraction (OF) and extra fraction (EF), are calculated for the selected slices. The SI is a criterion for the properly classified lesion area relative to the total areas of lesion, in both the gold standard and in the segmented image. The OF and EF specifies, the areas which have been correctly and falsely classified as lesion area relative to the lesion area in the gold standard. The similarity criteria are defined by (Fig. 2):

\[
SI = \frac{2 \times TP}{(2 \times TP) + FP + FN}
\]

\[
OF = \frac{TP}{TP+FN}
\]

\[
EF = \frac{FP}{TP + FN}
\]

In these equations, TP stands for true positive, FP for false positive, and FN for false negative. SI and OF for a good segmentation should be closer to 1 and EF be close to 0. In real time, a value for SI more than 0.7 represents a very good segmentation. The mean values of similarity criteria are categorized to the three patient categories and volumetric assessment of lesions volume between the fully automated segmentation and the gold standard are performed using correlation co-efficient (CC).
VI. COMPARISON PARAMETERS

A. MSE (Mean Square Error)

Mean Square Error MSE (Mean Square Error) refers to the process of squaring the differentiated quantities. It is defined as the average of the squares of the errors obtained by subtracting the input and the output values. MSE (Mean Square Error) is the cumulative squared error value between the input image \(I(i,j)\) and the segmented image \(K(i,j)\).

\[
\text{MSE (Mean Square Error)} = \frac{1}{mn} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} (I(i,j) - K(i,j))^2
\]


m - Number of rows present in an input image represented as a matrix.

n - Number of columns present in an input image represented as a matrix.

\(i = m\), to perform incremental operation for ‘rows’ in a loop statement.

\(j = n\), to perform incremental operation for ‘columns’ in a loop statement.

MSE value of the resulting image should be minimized. Reduced MSE values offer minimized error occurrence in the segmented MR brain images.

B. Peak signal-to-noise ratio (PSNR)

Peak signal-to-noise ratio, is an engineering term which ratios between the maximum possible power of a signal and the power of corrupting noise that affects the reliability of its representation.

\[
\text{PSNR} = 20 \log(\text{MAX}x) - 10 \log(\text{MSE})
\]

Where,

\(\text{MAX}x\) - the maximum pixel value of the image.

\(\text{MSE}\) - Mean Squared Error.

The normal value or the desired value for a quality image should always range from 40 to 60 dB.

C. Jaccard Index:

The Jaccard index, also known as the Jaccard similarity coefficient (developed by Paul Jaccard), is a statistic used for comparing the similarity and dissimilarity of sample sets. The Jaccard coefficient measures similarity between sample sets, and is defined as the ratio of size of intersection and the size of the union of the sample sets.

\[
J(A,B) = \frac{|A \cap B|}{|A \cup B|}
\]

D. Dice Overlap Index:

The presence and absence of data is given by,

\[
QS = \frac{2C}{A + B} = \frac{2(A \cap B)}{A + B}
\]

Here, \(A\) and \(B\) indicates the number of species in samples \(A\) and \(B\), respectively, and \(C\) represents the samples shared by both \(A\) and \(B\); \(QS\) usually in the range of 0 to 1, is the quotient of similarity. This expression is easily extended to profusion instead of presence/absence of species. The Sorensen index resembles to Dice’s coefficient which also has the same range.

D. Memory Storage Required:

Amount of space or memory required for the storage of output data is called as Memory storage required. If the number of images is increased in a process obviously there is a need to increase the memory required. So, if the memory required for storage is lower, then there can be more space to work on with the images.

E. Segmentation Accuracy:

Image segmentation is the course of grouping a digital image into multiple segments which are also known as super pixels. The need of segmentation is to simplify and/or change the representation of an image into pixels which can give higher results. Image segmentation is usually used to locate objects and boundaries (lines, curves, etc.) in images. As a whole image segmentation is labeling every similar group which can share some characteristics.

Previously mentioned values like the TP, FP, TN and FN are the four vital elements that are used to calculate the segmentation accuracy.

VII. RESULTS AND DISCUSSION

Input image is called upon using the algorithm with the help of MATLAB program where the region of interest (tumor region) is to be selected is shown in fig 3. Unlike the crop function which is present in the MATLAB tool box to crop out the specified region, here free hand sketch is applied to concentrate on the required ROI. In the earlier, either a square or rectangular part can alone be cropped whereas in this ROI method, it can of free form which is indicated in
fig 4. The ROI region is completely extracted from the original image which is illustrated in fig 5.

The tumor region which is obtained by using FCM algorithm shows more accurate segmentation of the image because of the increased values in the number of TP values obtained. The images thus obtained are listed and the values are compared with the results of the ROI algorithm and are listed below.

<table>
<thead>
<tr>
<th>Name of the Image</th>
<th>MSE</th>
<th>PSNR</th>
<th>ENTROPY</th>
<th>TC</th>
<th>DOI</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROI coronal T1</td>
<td>1.5458</td>
<td>0.8451</td>
<td>46.2936</td>
<td>59.2936</td>
<td>3.5522</td>
</tr>
<tr>
<td>ROI coronal T1</td>
<td>1.2568</td>
<td>0.7682</td>
<td>47.1381</td>
<td>60.9815</td>
<td>4.4290</td>
</tr>
<tr>
<td>ROI coronal T2</td>
<td>1.2486</td>
<td>0.7682</td>
<td>47.1381</td>
<td>60.9815</td>
<td>4.4290</td>
</tr>
<tr>
<td>ROI coronal T1</td>
<td>0.7682</td>
<td>0.7682</td>
<td>47.1381</td>
<td>60.9815</td>
<td>4.4290</td>
</tr>
<tr>
<td>ROI coronal T2</td>
<td>0.7682</td>
<td>0.7682</td>
<td>47.1381</td>
<td>60.9815</td>
<td>4.4290</td>
</tr>
<tr>
<td>ROI coronal T1</td>
<td>3.7357</td>
<td>0.5730</td>
<td>47.0187</td>
<td>60.9815</td>
<td>4.4290</td>
</tr>
<tr>
<td>ROI coronal T2</td>
<td>3.7357</td>
<td>0.5730</td>
<td>47.0187</td>
<td>60.9815</td>
<td>4.4290</td>
</tr>
<tr>
<td>ROI coronal T1</td>
<td>3.7357</td>
<td>0.5730</td>
<td>47.0187</td>
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</tbody>
</table>

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TABLE 2 - SIMILARITY CRITERION

<table>
<thead>
<tr>
<th>No. of Images</th>
<th>Similarity Criterion</th>
<th>Over Fraction</th>
<th>Extra Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ROI</td>
<td>FCM</td>
<td>ROI</td>
</tr>
<tr>
<td>10</td>
<td>0.8824</td>
<td>0.3636</td>
<td>0.8824</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.1176</td>
</tr>
</tbody>
</table>

VIII. CONCLUSION

The comparison parameter values which are tabulated for both the Region of Interest (ROI) and Fuzzy C Means (FCM) algorithms, clearly indicates that the later stands out best in the values like Mean Square Error (MSE), the Peak to Signal Noise Ratio and entropy values. The images obtained are also clearer and time consumption is comparatively low in that of the FCM algorithm. The number of true positive (TP) values is also high in number because of the objective function which looks for the best possible tumor segmentation from the given input image. Also, the memory required for the storage of the image is also minimized. Hence, on the lookout for the best possible algorithm for segmentation of tumor part from MR brain images, Fuzzy c-means (FCM) algorithm outsmarts the Region of Interest (ROI) algorithm with the minimized values of various comparison parameters.

REFERENCES


