Performance Metrics for Segmentation Algorithms in Brain MRI for Early Detection of Autism

Nagashree N, Premjyoti Patil, Shantakumar Patil, Mallikarjun Kokatanur

Abstract: Autism is an abnormal condition of human brain neurons, which makes individuals attention deficient, unable to speak and several other neurodevelopmental disorders as detected in the children with the age group of 2 to 5 years. However, autism is a neurological irregularity with more than one behavioral problem. Autism would be generally detected by behavioral symptoms, but early detection was not possible with behavioral approach. So, studying the structure of brain by using MRI image of the brain would be an efficient technique in early detection of autism. Various image classification and segmentation methods have been developed by many researchers. This work proposes a new performance metrics to find out efficiency of segmentation algorithms.

Keywords: ASD, Genetic Threshold, K-means, Segmentation.

I. INTRODUCTION

Autism is a serious developmental disorder which affects the child's ability to interact and behave. The neuroanatomy of autism is very difficult to analyze. Autism shows abnormalities in all the 4 regions of brain viz, parietal sector, frontal sector, occipital sector and lastly temporal sector. Abnormalities in the autistic brain can also affect in cerebellum, sensory portions of brain and corpus collosum, where the left and right hemispheres of the brain meet using axons. There is already an evidence that, the change in structure of cerebellum has directly related to neurological disorders. Genomic features have also been found out in this case. Autism can generally be detected by expert using behavioral therapy by interacting with the individuals specially in the age group of 2 and 7. But there is a need for very early detection of autism before the age of 1 or 2. That can be possible only by imaging studies and tests like CT scans, PET scans or MRI and fMRI imaging. Main challenge in Autism detection lies in the accuracy of the feature points extraction and once extraction done, how to classify.

There are many efficient segmentation algorithms available to extract the feature points and further various machine algorithms are researched in classifying feature points for efficient detection of autism in early age. Another challenge lies in medical testing or diagnosis since autism is a behavioral related psychological factor rarely people go for medical imaging tests.

To detect the efficiency of the segmentation algorithms listed, there is a requirement to find out the metrics to detect the performance of each segmentation algorithm and that is the further part of this research paper.

The very first step in autism detection is pre-processing where the noise in the image is removed by various mathematical models. Next comes Image segmentation. It refers to the process of diving a digital image into multiple parts. The main aim of segmentation is to give different and clear view for the original image.

The segmentation of image results in partitioning or subset of main image. [1]. Therefore, medical image segmentation plays a significant role in clinical diagnosis. Generally medical imaging is very challenging task because they have poor resolution [2]. There are many medical imaging techniques to study the anatomy of human brain. Different methods are PET, CT, MRI, fMRI [3]. Since behavioral diagnosis of autism required lots of expert intervention and difficult to detect in early age there is a need for imaging methods [4]. So this would in fact require efficient segmentation methods with some selected properties of images [5]. Many image segmentation algorithms derives its parts based on two criteria: region based and intensity based [6]. In case of first method, the algorithm is based on partitioning the image on intensity basis and where as the later approach evaluates on coordinate area axis. The literature review says there are number of segmentation methods such as histogram based methods, edge-based methods, artificial neural network based segmentation methods, physical model based approaches, region-based methods (region splitting, growing, and merging), and clustering methods (Fuzzy C-means clustering, K-means clustering, Mean Shift, and Expectation Maximization) [7–9].Since image classification and segmentation plays a very important role in pattern matching for any given medical imaging methods, there is no universally accepted method for it. The efficiency of the algorithm depends on the kind of problem associated in the research. [10].

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II. METHODOLOGY

The proposed method of brain MRI in autism detection includes the following steps:

a) Dataset Representation

In our proposed system we have made use of 500 brain MRI of autistic patients which we have collected from ABIDE.

b) Pre-Processing

Preprocessing is the technique of removing noises from the MRI images. Region based binary mask extraction: This method of mask extraction is carried out by dividing the whole image into several parts called regions. Region masking is done by selecting a threshold and there are two ways of doing this:

One is to find out max-min difference and the other is calculating average of blocks. Hence this technique is applied for brain making in original MRI data.

c) Segmentation

Segmentation is the extracting of region of interest from the original image. Following segmentation methods are implemented and compared:

1. K means Clustering Algorithm

K means clustering mathematical model:

$$ca_1 \cup ca_2 \cup ca_3 \ldots ca_k = p \sum_{i=1}^{k} \sum_{x \in ca_i} 1 \left\| t - \frac{1}{|ki|} \sum_{t_j \in k_j} t_j \right\|^2$$

The algorithm steps are as follows:

Step 1: Make clusters into one group called k groups and k is fixed.

Step 2: Select any clusters and find the centroid

Step 3: Fix the object to the nearest cluster centroid, Euclidian distance formula helps in finding the nearest node or cluster.

Step 4: Identify the cluster centroid of all objects, repeat steps 2-4 until, in continuous rounds identical object assigns to same clusters.

2. FCM Segmentation Method:

Mathematical model:

$$j_m \sum_{i=1}^{n} \sum_{j=1}^{c} u_{ij}^m \|x_i - c_j\|^2, 1 \le m < \infty$$

Algorithm:

Step 1: Initialize $p=[P_{ij}]$ matrix

Step 2: In N-step: find the centers vectors $C\{K\} = [C_j]$ with U

$$c_j = \frac{\sum_{i=1}^{n} u_{ij}^m . x_i}{\sum_{i=1}^{n} u_{ij}^m}$$

Update P (K), P(K-1).

$$u_{ij}^m = \frac{1}{\sum_{k=1}^{c} \left(\frac{\|x_i - c_j\|}{\|x_i - c_k\|} \right)^2}$$

Step 3: If

$$\left\| p^{(k+1)} - p^{(k)} \right\| < \delta$$

Terminate the process else go back to step 2.

3. Genetic Threshold Algorithm:

The GN algorithm of populace amount begins with nth random size. Finally, it will select member with good size.

Pseudo code:

1. Read the image
2. Find out Image Histogram
3. Populate initial set of chromosomes
4. For i=0 to number of iterations
5. While (size(pop)>size (Newpop))
6. Select two chromosomes Ch1, Ch2.
7. If (rand < crossover rate) then
8. Perform crossover Chnew1, chnew2
9. IF (rand<mutation rate) then
10. Mutate chnew1
11. If (rand<mutation rate) then
12. Mutate chnew2
13. Add newpop.

III. PERFORMANCE METRICS OF THE SEGMENTATION ALGORITHMS

Method 1: Pmax Metric

In the segmentation of Brain MRI images, many factors are taken into consideration in efficient detection of segments.

Feature extraction is one such method to segment the image. The segmentation efficiency can be detected by finding the more features in any algorithm. Out of the methods selected for segmentation, a common mathematical model is proposed to analyze performance.

Step 1: Populate an array A = {a_1, a_2, a_3, ………..} where a_1, a_2, …… are the set of coordinate points obtained out of segmentation algorithm.

Step 2: Calculate the area of the region from the coordinate points obtained

$$Area_{region} = \int_{0}^{1} xdx$$

Step 3: Find out the centroid of the coordinate points. Centroid can be calculated by taking 4 outermost coordinate points. Let O_1 and O_2 be the left and right outermost feature point and O_3 and O_4 are the top and bottom most features.

Calculate $d_1=(O_1+O_2)/2$ and

$$d_2=(O_3+O_4)/2$$

Centroid $C = d_1+d_2$ store the value of C_i for each MRI brain image.

Step 4: Find the threshold value by repeating step 2 and 3.

Step 5: Find the distance between Centroid C and each element in the array

$$A = \{a_1, a_2, a_3, \ldots\ldots\}.$$

If $D <=$ threshold, $D_{in} = \{a_1, a_2, \ldots\}$

Else

$$D_{out} = \{a_1, a_2, \ldots\ldots\}$$

Step 6: Find N = count of $\{D_{in}\}$ for each algorithm i.e N_1, N_2 and N_3 and

$$N_{max} = \{N_1, N_2, N_3\}$$

Here N_{max} is maximum no. of feature points falling within interested region.

Method 2: Percentage Metric

From the collected feature points calculate the percentage of autistic features against the normal feature points to get $f(x,y)$ where x and y are the coordinate points of feature points of segmented image

$$f(x,y) = \frac{N_{(i)autistic}}{N_{(i)normal}} \times 100$$

IV. RESULTS AND DISCUSSION

Brain has 2 hemispheres, left and the right. To interconnect these two hemispheres of brain, corpus collosum has 200 million axons. Each hemisphere of brain is meant for some specific functionality. For a better decision-making ability or to process some complex information, both hemispheres of the brain are required and there comes the importance of corpus collosum.

| Segmentation	Autism
K-Means	
FCM	
Genetic Threshold	
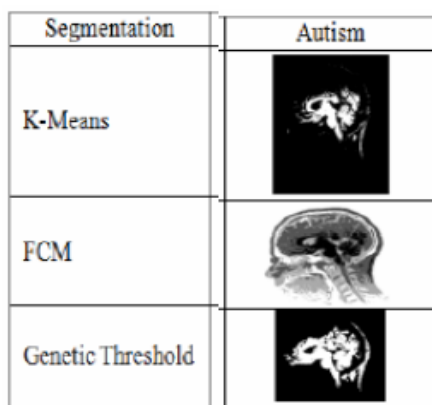
Figure 1: Corpus callosum of brain for autistic individual

But when corpus collosum is working properly, such people may behave abnormal. Physically those persons may be heathy, but they are mentally abnormal.

The Figure 1 shows the corpus collosum status of autistic and normal brain.
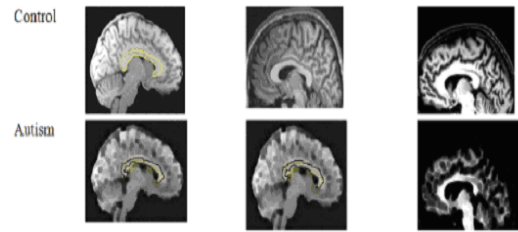
Figure 2: Gray matter identification of autistic and control individuals
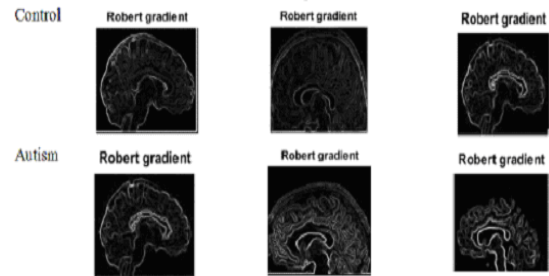
Figure 3: Edge detection of autistic and control individuals

Calculate the Area of Corpus Callosum

Once the segmented image is obtained, using binarization technique, the area of the corpus collosum is calculated for every feature point obtained.

Table 1. shows the performance metrics of proposed segmentation algorithm using binarization technique. The values are calculated for indicated area of corpus callosum. The calculated values are 396 pixels in case of normal brain and 253 pixels for autistic child's brain. From these calculated values, it is observed that the values of corpus callosum of autistic are reduced than normal.

Table 1: Comparison in Pixel numbers to distinguish between autistic and normal brain

Area of brain	Variants	Performance metrics in pixels
Corpus Collosum	Autistic Brain	253
Corpus Collosum	Normal Brain	396

Using the performance metrics discussed earlier, autistic brain features are reduced than the features of normal brain. Figure 4 shows the graphical representation of plotted feature points using the segmentation algorithm.
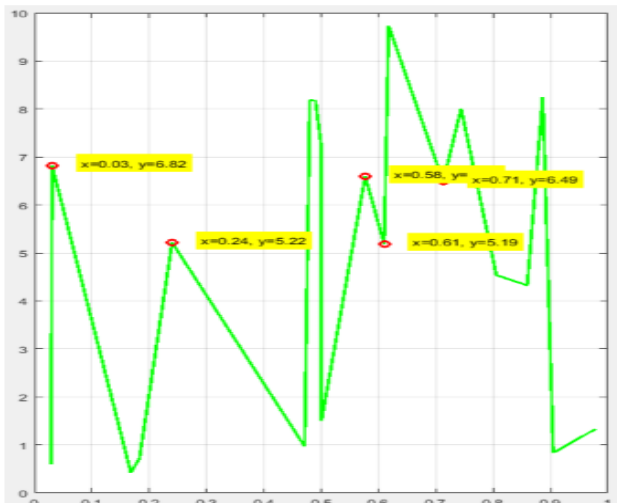
Figure 4: Result of image segmentation feature extraction represented as coordinate points

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