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A Study of Brain Tumor MRI Image Using Distance Based Clustering Algorithms

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***Abstract*— Brain tumor segmentation is a challenging problem. The medical expert can analyze the MRI (Magnetic Resonance Imaging) but this activity is error-prone and time consuming process. Data clustering is the process of grouping similar objects. Existing brain tumor segmentation methods use Euclidean distance metric. In this paper, a study of hard and fuzzy methods based on different distance metrics – Manhattan and Chebyshev used for brain tumor segmentation is done. The result of Adaptive Fuzzy K-means (AFKM) is compared with K-means and Fuzzy K-means (FKM) algorithms. The AFKM based on Chebyshev distance gives better result than K-means and FKM techniques in terms of accuracy and quantitative measurements.**

Keywords— Image Segmentation, Clustering, K-means, FKM, AFKM, MRI, Distance Metrics.

1. INTRODUCTION

Human brain is the important organ which controls all our physical and mental tasks. Brain tumor is an abnormal or uncontrolled growth of cells. It may increase pressure in the brain and may damage the central nervous system. Recently, brain tumor detection is one of the significant tasks. Brian tumor is broadly classified as benign and malignant. A benign tumor is not cancerous and the tumor cells do not spread to other parts of our body. Malignant tumor is cancerous and the cells grow out of control. It does not have clear borders [1].

Radiologists examine the patients by using various imaging techniques such as X-rays, Ultra-sound, Computerized Tomography (CT) scan, Positron Emission Tomography (PET), and Magnetic Resonance Imaging (MRI). Medical imaging plays a key role to diagnose the brain tumor and helps radiologists for better treatment [2].
X-rays: They measure the density of tissues. They are used to analyze and see bone disease, bone breaks, fracture, degeneration, dislocations and infections.

Ultra-sound: It is used to find the locations of surfaces within tissues and differentiates surfaces from fluids.
CT scan: It produces high-quality, detailed images of the body. It produces detailed images of blood vessels, bones, organs, and soft tissue. It is more powerful than X-rays.
PET: It measures the physiological functioning of a brain. It is mainly used to study the expression of specific genes in the brain, neurotransmitters and actions of pharmaceutical drugs.

MRI scan: It provides detailed information about cellular structure and brain tumor anatomy. It does not contain any radiations. It is an excellent tool used by doctors to detect abnormality in brain. It is more comfortable than other scanning methods due to high in tissue contrast, better differentiation of tissues and has fewer artifacts.
Image segmentation is the process of sub-dividing an image into sets of pixels. It helps in locating the brain tumor boundary region appropriately. The segmentation techniques can be categorized into edge based segmentation, threshold based segmentation, region based segmentation and cluster based segmentation. In edge based segmentation techniques, the abrupt change in intensity values is taken into concern for object extraction. In threshold based segmentation techniques, the objects from the image are extracted on the basis of a particular threshold. This technique is appropriate for images with different intensities of pixels. In region based segmentation techniques, the image is divided into regions that are similar intensities on the basis of some predefined criterion. In cluster based segmentation techniques, an image is divided into a number of clusters based on the value of membership functions allotted to each pixel in the image [3]

Clustering is a method that attempts to partition a set of pixels into groups such that pixels in each subset are similar to each other. Clustering methods are broadly classified into hard and soft clustering. The hard clustering technique, K-means is simple and widely used method for image segmentation [4]. But, it is not suited for real world applications. The soft clustering technique, Fuzzy K-means is an efficient method. It permits us data elements belong to more than one cluster. Recently

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AFKM is found success in solving image segmentation problems. Distance measure plays a key role in clustering analysis. In this paper, segmentation via various clustering methods is used to segment the MRI brain image based on different distance measures such as Euclidean, Manhattan and Chebyshev

The remainder of the paper is organized as follows: In section 2, related work is described. The methodology is explained in section 3. Results and discussion are presented in section 4. Finally, conclusion is given in section 5.

RELATED WORK

This section gives with the works related to analysis of brain tumor detection in MRI images. Logeswari and Karnan [5] described segmentation method in two phases. They have studied the performance of the MRI image in terms of weight vector, execution time and tumor pixels detected. Vasuda and Satheesh [6] developed improved fuzzy c-means algorithm for MR brain image segmentation. In their proposed method, the computational rate is improved by modifying the cluster center and membership values. TamijeSelvy et al. [7] analyzed various clustering techniques such as K-means, SOM, Hierarchical Clustering and Fuzzy C-Means to track tumor objects in Magnetic Resonance (MR) brain images. Padole and Chaudhari [8] reviewed various segmentation methods in medical images. They have combined the mean shift and normalized cut methods in their new approach. Patil and Bhalchandra [9] proposed a strategy to detect and extraction of brain tumour from patient's MRI scan images of the brain by using MATLAB software. Vijay and Subhashini [10] describe an efficient method for automatic brain tumor segmentation for the extraction of tumor tissues from MR images. They have proposed K-means algorithm for better performance and good results.

Alan Jose et al. [11] proposed segmentation methods for brain tumor using K-means and Fuzzy C-means algorithms. Before the process of algorithm, the noise present in the MR image is first removed. The noise free image is given as input to the clustering algorithms for extracting tumors from MR image. Vishal Shinde et al. [12] proposed a segmentation method that uses the K-means clustering technique to identify the tumor in MRI. In their work, K-means method is used to convert a given RGB image into gray scale image and then separate the position of tumor objects. The aim of their study is the design of a computer system that able to identify the presence of digital images of the brain and to accurately define its borderlines. Sagar Anil Kumar and Chandra Sekhar Rao [13] implemented K-means based segmentation method to detect brain tumor and cancer cells. This segmentation method enhances the growth boundaries and fast with other clustering methods. Their algorithm produces reliable results with less execution time and less number of iterations. Rabab Saadoon Abdoon et al. [14] implemented the Fuzzy C-Mean clustering to segment three abnormal brain MR images. The results indicate that, for high membership values, error increases due to the high correlation between the brain tissues. Siddhi Nerurkar[15] presented the two efficient image segmentation algorithms – K-Means and Region Growing Techniques for brain MRI images. Cancerous Tumors have been detected from the brain MRI scans using these two techniques. Region Growing Technique is found to be more accurate than K-Means algorithm. Gayathri andVasanthi [16] presented the K-means and fuzzy c-means algorithms for image segmentation. The brain tumor is detected and its exact location is identified.

METHODOLOGY

Pre-processing

Pre-processing is essentially for to correct and adjust the image for further study. Different types of filtering techniques are available in the literature. These filters are used to suppress the noise, smoothen and enhance the image and improve the quality the image. Some important filters are Median filter, Adaptive Median filter, Mean filter, Adaptive mean filter, Gaussian Smoothing filter and Wiener filter. These filters are used for MRI brain image pre-processing. The median filter is one of the most famous filters which is simple to implement. It is a nonlinear digital filtering technique, used to remove noise from an image. Such noise reduction is a typical pre-processing step to improve the results of later processing. It is a good technique to remove salt and pepper type of noise. It works by moving through the image pixel by pixel, replacing each value with the median value of neighboring pixels. [17]

Distance Metrics

Distance measure plays an important role in clustering. It is essential to identify the manner in which the data elements are related and how the data elements are similar and dissimilar with each other. The important properties

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of distance metrics are non-negativity, symmetry, identification, definiteness and triangle inequality [18].
If the points have 'n' dimension such as $p = (x_1, x_2, ... x_n)$ and $q = (y_1, y_2, ... y_n)$ then various distance metrics are calculated from the following table:

Distance Metric	Formula d(p,q)
Euclidean	$\sqrt{\sum_{i=1}^{n}(x_i - y_i)^2}$
Manhattan	$\sum_{i=1}^{n} \| x_i - y_i \|$
Chybyshev	$Max_{\forall i=1,2,...n} \| x_i - y_i \|$

Clustering Techniques

The cluster analysis is an optimization problem in which a given function consisting of intra-cluster similarity and inter-cluster dissimilarity needs to be optimized. It has a wide range of applications in many different areas like marketing research, image analysis, image segmentation, medicine, character recognition, banking and finance web analysis, computer forensics etc.

K-means Clustering Algorithm

K-means clustering technique is one of the simplest hard clustering techniques. Given 'n' number of data elements, this algorithm groups these data into specified clusters. The data elements belong to the same cluster are similar in nature and those belonging to different clusters are different in nature [19] [20].

Let $X = \{x_1, x_2 ... x_n\}$ be the set of data points and $c = \{c_1, c_2 ... c_k\}$ be the set of cluster centers.

Step1: First select 'k' cluster centers randomly.

Step 2: Calculate the distance between the pixels and cluster centers. Choose the suitable distance function.

Step 3: Assign each pixel x_i to its nearest cluster center c_j

Step 4: Calculate the new cluster center c_j using

$$c_j = \frac{\sum_{x_i \in j} x_i}{n_j}$$

where n_j is the number of pixels belonging to the j-th cluster

Step 5: Repeat the steps (2) to (4) until convergence is reached.

Fuzzy K-means Clustering Algorithm

Fuzzy K-means (FKM) or Fuzzy c-means (FCM) algorithm is a popular data clustering technique for analysis of MRI images [21]. It is an extension of K-means algorithm. FKM is a clustering algorithm in which each data point belongs to cluster to a degree specified by a membership grade. The pixels near to the cluster center have high membership degree towards the particular cluster center [22].

Parameters: u_{ij} - fuzzy partition membership values; x_i - data values; z_j - jth cluster center; m – fuzziness exponent;
ε - iteration error

Step 1: Initialize $U^{(0)}$

Step 2: Determine z_j, $j = 1, 2, ... c$, using

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

Step 3: Determine the suitabledistance measure

Step 4: Calculate the objective function value J_m using

$$J_m = \sum_{j=1}^{c}\sum_{i=1}^{n} u_{ij}^m d_{ij}^2$$

Step 5: Update $U^{(k+1)}$ using

$$u_{ij}^{(k+1)} = \frac{1}{\sum_{k=1}^{c}\left(\frac{d_{ij}^2}{d_{ik}^2}\right)^{\frac{1}{m-1}}};$$

$$1 \le i \le n; 1 \le j \le c$$

Step 6: If $\| U^{(k+1)} - U^{(k)} \| < \varepsilon$ then stop; otherwise go to step 2

Adaptive Fuzzy K-means Clustering Algorithm

AFKM is proposed by Sulaiman et al. This method is widely used in image segmentation [23] [24][25]. In this paper, AFKM clustering algorithm with new distance measures is proposed.
The objective function value of AKFM is calculated using the equation

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$$J = \sum_{k=1}^{n_c} \sum_{t=1}^{n} (M_{kt}^{m}) d_{tk}^{2}$$

where M_{kt}^{m} is the fuzzy membership function and m is the fuzziness exponent
The cluster center is determined using the equation

$$C_k = \frac{\sum_{t=1}^{N} (M_{kt}^{m})' v_t}{\sum_{t=1}^{N} (M_{kt}^{m})'}$$

where $(M_{kt}^{m})'$ is the new membership function and is defined as

$$(M_{kt}^{m})' = M_{kt}^{m} + \Delta M_{kt}^{m}$$

$$\Delta M_{kt}^{m} = \alpha (c_k)(e_k)$$

and e_k is the error of belongingness.

RESULTS AND DISCUSSION

In this paper, the following MRI brain image taken from data base is selected for analysis by the clustering algorithms based on different distance measures. The original image of MRI brain images is shown in fig. 1. The results are analyzed based on accuracy, F(I) and mean squared error (MSE) [26] [27].
The various performance measures are described as follows:

$$Accuracy = \frac{TN + TP}{TN + TP + FN + FP}$$

where TN is true positive, TP is true positive, FN is false negative and FP is false positive.

$$F(I) = \sqrt{R} \sum_{i=1}^{R} \frac{e_i^2}{\sqrt{A_i}}$$

$$MSE = \frac{1}{N} \sum_{j=1}^{M} \sum_{i \in s_j} \| x_i - c_j \|^2$$


(a)


(b)

Fig 1. Original Image of MRI Brain Images

Tables I to VI and Fig. 2 to 7 show the results of various performance measures for the selected image. From the results, the AFKM clustering method based on Chebyshev distance measure produces better result than the other clustering methods, namely K-Means and FKM for different metrics.

Table I: Evaluation of Accuracy for Image 1

Algorithm	Distance Metric		
	Euclidean	Manhattan	Chebyshev
K-means	65	65	73
FKM	77	76	77
AFKM	85	85	86

Table II: Evaluation of Accuracy for Image 2

Algorithm	Distance Metric		
	Euclidean	Manhattan	Chebyshev
K-means	60	67	73
FKM	77	77	78
AFKM	83	84	85

Table III: Evaluation of F(I) for Image 1

Algorithm	Distance Metric		
	Euclidean	Manhattan	Chebyshev
K-means	6807.95	6588.95	6329.93
FKM	5918.95	5870.88	5838.92
AFKM	5825.92	4847.28	4289.76

Table IV: Evaluation of F(I) for Image 2

Algorithm	Distance Metric		
	Euclidean	Manhattan	Chebyshev
K-means	6807.96	6589.95	6328.96
FKM	5918.18	5889.45	5839.78
AFKM	5825.98	4847.78	4090.74

Table V: Evaluation of MSE for Image 1

Algorithm	Distance Metric		
	Euclidean	Manhattan	Chebyshev
K-means	984.38	953.48	917.78
FKM	846.78	820.83	816.76
AFKM	690.48	629.79	609.56

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Table V: Evaluation of MSE for Image 2

Algorithm	Distance Metric		
	Euclidean	Manhattan	Chebyshev
K-means	984.34	954.38	916.78
FKM	846.78	830.56	817.76
AFKM	689.46	629.79	617.65

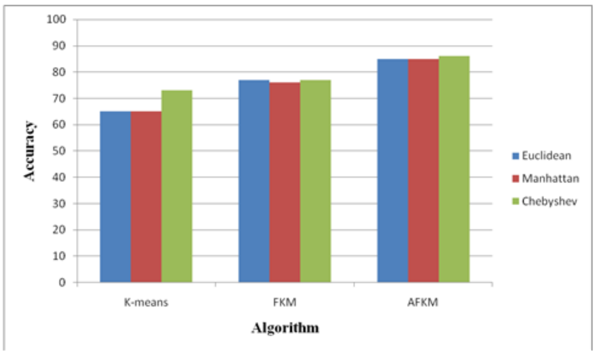

Fig. 2 Evaluation of Accuracy for Image 1

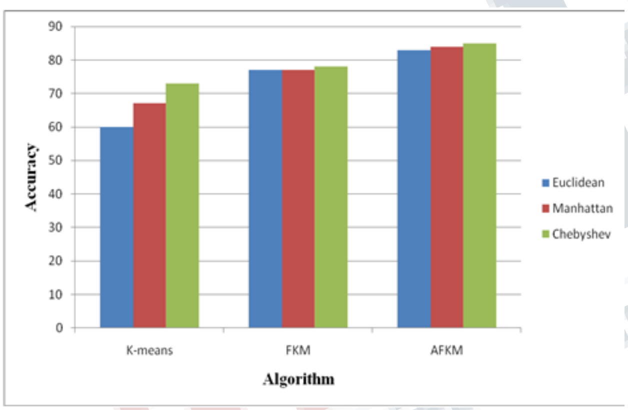

Fig. 3 Evaluation of Accuracy for Image 2

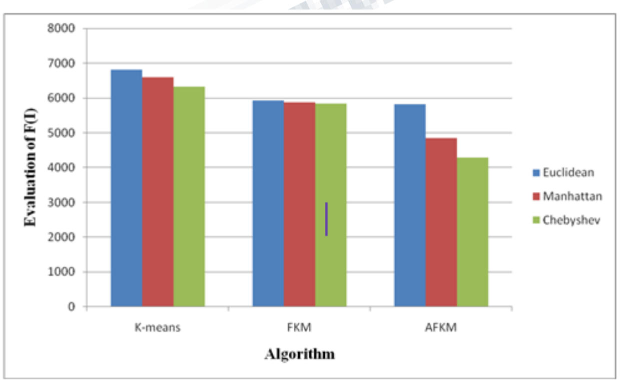

Fig. 4 Evaluation of F(I) for Image 1

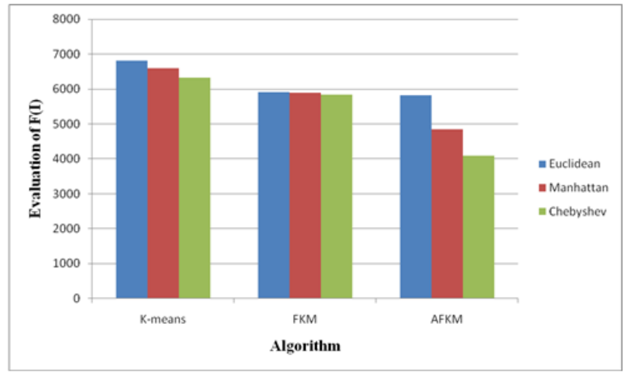

Fig. 5 Evaluation of F(I) for Image 2

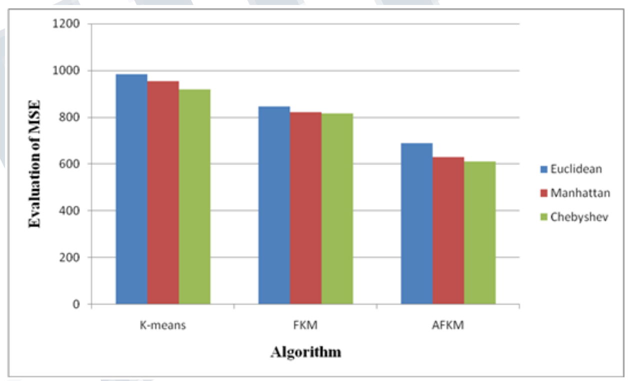

Fig. 6 Evaluation of MSE for Image 1

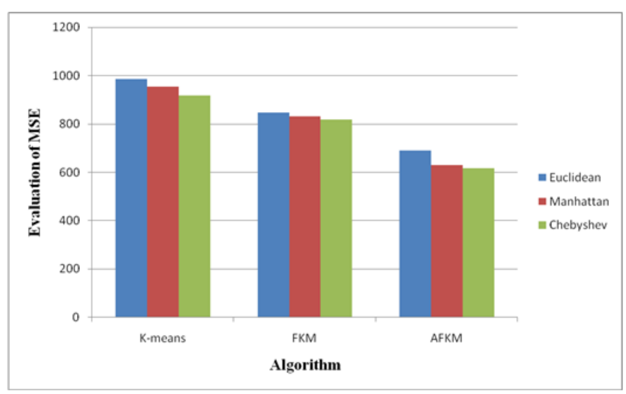

Fig. 7 Evaluation of MSE for Image 2

CONCLUSION

Brain tumors are caused by abnormal growth of cells insider the brain. Brain tumor segmentation is one of the important medical diagnostic techniques. The performance of brain tumor segmentation is evaluated using K-means, FKM and AFKM Clustering Algorithms with three distance measures such as Euclidean, Manhattan and Chebyshev distance metrics based on MRI Images. From the comparison, it is observed that the AFKM Clustering Algorithm using Chebyshev distance gives better results than K-means and FKM in terms of Accuracy, and Quantitative Measurements.

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