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Automatic Determination Number of Cluster for NMKFC-Means Algorithms on Image Segmentation

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***Abstract*:** *Image segmentation plays an important role in image analysis. Image segmentation is useful in many applications like medical, face recognition, crop disease detection, and geographical object detection in map. Image segmentation is performed by clustering method. Clustering method is divided into Crisp and Fuzzy clustering methods. FCM is famous method used in fuzzy clustering to improve result of image segmentation. FCM does not work properly in noisy and nonlinear separable image, to overcome this drawback, KFCM method for image segmentation can be used. In KFCM method, Gaussian kernel function is used to convert nonlinear separable data into linear separable data and high dimensional data and then apply FCM on this data. KFCM is improving result of noisy image segmentation. KFCM improves accuracy rate but does not focus on neighbor pixel. NMKFCM method incorporates neighborhood pixel information into objective function and improves result of image segmentation. New proposed algorithm is effective and efficient than other fuzzy clustering algorithms and it has better performance in noisy and noiseless images. In noisy image, find automatically required number of cluster with the help of Hill-climbing algorithm.*

***Keyword*:** *Component: Clustering, Fuzzy clustering, FCM, Hill-climbing algorithm, KFCM, NMKFCM*

I.Introduction

Image segmentation is a major topic for many image processing research. Image segmentation is critical and essential component of image analysis system. Image segmentation is process of partitioning image into different segment (set of pixel). Segment consist set of similar pixel by using different properties of pixel like intensity, color, tone, texture etc. The goal of image segmentation is to simplify or change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is performed using four approaches like Clustering, Thresholding, Region Extraction and Edge Detection,. Image segmentation plays more crucial role in many applications like medical image, pattern recognition, machine vision, computer vision, video surveillance, geographical object detection, image analysis, crop disease detection.

Clustering is one approach to perform image segmentation on image. Clustering is a process of partitioning or grouping a given set of unlabeled objects into number of clusters such that similar objects are allocated to one cluster [1]. Clustering method perform by using two main approaches like crisp clustering and fuzzy clustering[2]. Crisp clustering is to process in which finding boundary between clusters. In this object belong to only one cluster. Fuzzy clustering has better solution for this problem, in fuzzy clustering object can belong to more than one cluster.

Fuzzy C-means (FCM) algorithm is most widely used clustering technique which follows fuzzy clustering for image segmentation. FCM clustering algorithm was first introduced by Dunn and later extended by Bezdek [3][1]. FCM is method of clustering to which allow one object belongs to two or more clusters. FCM is introducing fuzziness with degree of membership function of every object and range of membership function between 0 and 1[4]. Aim of FCM is to minimize value of objective function and perform partition on dataset into n number of clusters. FCM provide better accuracy result than HCM in noiseless image. FCM is not working properly in noisy image and failed in nonlinear separable data, to overcome this drawback Kernel Fuzzy C-means (KFCM) algorithm is used. Kernel function is use to convert nonlinear separable data into linear separable data and low dimension into high dimensional feature space[5]. KFCM is not adequate for image corrupted by impulse noise. KFCM is not to focus on neighbor pixel. Propose Novel Kernel Fuzzy C-means (NMKFCM) algorithm which is to assimilate neighbor term in objective function and amend result over KFCM and FCM in noisy and noiseless image[6]. NMKFCM is very beneficial and useful method for image segmentation.

II.Clustering Algorithm

Definition: Let F be the set of all pixels and P( ) be an uniformity (homogeneity) predicate defined on groups of associated pixels, then segmentation is a partitioning of the set F into a set of connected subsets or regions $(s_1, s_2, \dots, s_n)$ such that $\bigcup_{i=1}^{n} s_i = F$ with $s_i \cap s_j = \emptyset$ when $i \neq j$. The uniformity predicate $P(S_i)$ is true for all regions S_i and $P(S_i \cup S_j)$ is false when S_i is adjacent to S_j. Image segmentation approaches can be divided into four categories: Thresholding, Clustering, Edge detection, Region extraction Clustering is process of partitioning or grouping a given set of unlabeled objects into number of clusters such that similar object are allocated into one cluster. Clustering is performed with minimize value objective function for image segmentation. Clustering methods can be classified into supervised clustering and unsupervised clustering [6]. A cluster is a collection of data objects that are similar to one another within the same cluster and are dissimilar to the objects in other clusters. Clustering is classified into crisp and fuzzy clustering.

A. Fuzzy Clustering Algorithm (FCM)

FCM algorithm was introduced by Dunn and extended by Bezdek. Aim of fuzzy c-means algorithm is to minimize an objective function [7]. The fuzzy c- mean algorithm is better than the k-mean algorithm, since in k-mean algorithm, feature vectors of the data set can be partitioned into hard clusters, and the feature vector can be exactly a member of one cluster only. Instead, the fuzzy c-mean relax the condition, and it allows the feature vector to have multiple membership grades to several clusters, Suppose the data set with known clusters and a data point which is close to both clusters but also equidistant to them. Fuzzy clustering gracefully handles with such dilemmas by assigning this data point equal but partial memberships to both clusters that are the point may belong to both clusters with some degree of membership grades varies from 0 to 1.

FCM is an iterative clustering process that generate optimal c partition by using minimize weighted within group sum of squared error objective function J_m

$$J_m = \sum_{j=1}^{c} \sum_{i=2}^{N} U_{i,j}^{m} d_{i,j}^{2} \qquad (1)$$

Where:

N: The number of patterns in X , C: The number of clusters, U_{ij}: The degree of membership x_i of in the j^{th} cluster , W_j: The prototype of the center of cluster j ,d_{ij}: Distance measure between object X_i and cluster center W_j , m: The weighting exponent on each fuzzy membership.

The FCM algorithm focuses on minimizing objective function Jm, focus to the following constraints on U:

$$U_{ij} \in [0,1], \; i=1,2,3\ldots\ldots N, \text{ and } j=1,2,3\ldots.C$$

$$\sum_{j=1}^{c} U_{ij} = 1, \qquad i=1, 2, 3\ldots\ldots\ldots..N$$

$$0 < \sum_{i=1}^{N} U_{ij} < 1, \qquad j=1, 2, 3\ldots\ldots.C$$

Objective function j_m describe a constrained optimization problem, which can be altered to an unconstrained optimization problem by using Lagrange multiplier technique. By using this calculates membership function and update cluster center separately.

$$U_{ij} = \frac{1}{\sum_{l=1}^{c} \left(\frac{d_{ij}}{d_{il}}\right)^{\frac{2}{(m-1)}}} \qquad (2)$$

i=1,2……..N, and j,l=1,2,……………C

If d_{ij}=0 then U_{ij}=1 and U_{ij}=0 for $1 \neq j$

And calculate cluster center using following step

$$W_j = \frac{\sum_{i=1}^{N} (U_{ij})^{m} x_i}{\sum_{i=1}^{N} (U_{ij})^{m}}, \qquad (3)$$

j=1,2…………C

Algorithm:

J_m can be obtain through an iterative process, which is achieved by following steps

INPUT

1. X={X_1, X_2….X_n}, Data set
2. C, 2≤C≤n, n is number of cluster
3. Set value of Ɛ, it is stopping criteria parameter
4. Initialize membership function U_{ij}^{0} using data set and cluster.
5. Calculate initial cluster center W_0= (w_{01}, w_{02}…w_{0c})

OUTPUT

W_j = {W_0, W_1, W_2……W_j} , Final center of clusters.

Algorithm

1. Set loop counter p=0
2. Calculate C cluster center W_j^{p} with U^{p} by using equation (3)
3. Calculate membership function U^{p+1} by using equation. (2).

4. If $\{U^p - U^{p+1}\} < \varepsilon$, then stop otherwise set p=p+1 and go to step 2.

C. Kernel Method

Kernel method is an algorithm that implicitly performs, by replacing the inner product with an appropriate Mercer Kernel, a non-linear mapping of the input data to a high dimensional Feature Space. A kernel function is a generalization of the distance metric that measures the distance between two data points as the data points are mapped into a high dimensional space in which they are more clearly separable [8].

Consider a non-linear mapping function $\Phi : I = \mathbb{R}^2 \rightarrow F = \mathbb{R}^3$ from the 2-dimensional input space I into the 3-dimensional feature space F, which is defined in the following equations:

$$\emptyset(\vec{x}) = \left(x_1^2, \sqrt{2x_1x_2}, x_2^2\right)^T \quad (4)$$

Hyperplane of form linear separable dataset.

$$\vec{w}^T\vec{x} + b = 0$$

Taking the equation for a separating hyper plane Eq.(4) into account get a linear function in $\mathbb{R}^3$:

$$\vec{w}^T\emptyset(\vec{x}) = w_1x_1^2 + w_2\sqrt{2x_1x_2} + w_3x_2^2 = 0 \quad (5)$$

It is worth mentioning, that Eq.(5) is an elliptic function when set to a constant c and evaluated in $\mathbb{R}^2$.

With an appropriate mapping function use linear classifier in F on a transformed version of the data to get a non-linear classifier in I with no effort. After mapping non-linear separable data into a higher dimensional space, find a linear separating hyperplane. Only depend on the mapped data through dot products in some feature space F. The explicit coordinates in F and even the mapping function become unnecessary when we define a function $K(\vec{x}_i, \vec{x}) = \emptyset(\vec{x}_i)^T\emptyset(\vec{x})$ so called kernel function, which is directly determines the value of the dot product of the mapped data points in some feature space. The following example of a kernel function K demonstrates the calculation of the dot product in the feature space using $K(\vec{X}, \vec{Z}) = \left(\vec{X}^T, \vec{Z}\right)^2$ and inducing the mapping function

$$\Phi(\vec{x}) = \left(x_1^2, \sqrt{2}x_1, x_2, x_2^2\right)^T \quad (6)$$

$$\vec{x} = (x_1, x_2)$$

$$\vec{z} = (z_1, z_2)$$

$$K(\vec{X}, \vec{Z}) = \left(\vec{X}^T, \vec{Z}\right)^2$$

$$= (x_1z_1 + x_2z_2)^2$$

$$= \left(x_1^2, \sqrt{2x_1x_2}, x_2^2\right)^T \left(z_1^2, \sqrt{2z_1z_2}, z_2^2\right)$$

The advantage of kernel function is that the complexity of the optimization problem remains only dependent on the dimensionality of the input space and not of the feature space.

Kernel function K(X, Z) has some form, these form mention below:

1) Linear Kernel function: $K(x,z) = x^Tz$
2) Polynomial Kernel function: $K(x,z) = (x^Tz + \theta)^d$
3) Gaussian Kernel function: $K(x,z) = exp\left(-\frac{\|x-z\|^2}{\sigma^2}\right)$
4) Sigmoid Kernel Function: $K(x,z) = tanh\left(\alpha\left((x^Tz) + \theta\right)\right)$

D. Kernel Fuzzy c-means Algorithm (KFCM)

The FCM algorithm use Euclidian distance to calculate distance between cluster center and data object. Euclidian distance is not working properly in noisy data so FCM fail in noisy and nonlinear data set. To overcome this drawback, Kernel Fuzzy C-means algorithm is used. KFCM method consists of kernel information with FCM [9]. KFCM is performing map input data into a feature space with higher dimensional and convert nonlinear separable data into linear separable data by using Kernel method. KFCM having more accuracy than FCM in noisy image and it clearly classify noisy object into clusters. KFCM membership matrix U is allowed to have value between 0 and 1. KFCM is iterative clustering methods that generate optimal c partition by using minimize objective function $J_{kfcm.}$

$$J_{km}(U,W) = 2\sum_{j=1}^{c}\sum_{i=1}^{N}U_{ij}^{m}\left(1 - K(X_i, W_j)\right) \quad (7)$$

In this objective function Gaussian kernel function is used.

$$K(X,Y) = exp\left(-\frac{\|x-y\|^2}{\sigma^2}\right)$$

$$d_{ij} = dist\left(\emptyset(X_i), \emptyset(W_j)\right)$$

$$= \sqrt{\left\|\phi\left(X_i - \phi(W_j)\right)\right\|^2}$$
$$= \sqrt{\phi(X_i) * \phi(X_i) - 2\phi(X_i) * \phi(W_j) + \phi(W_j) * \phi(W_j)}$$
$$= \sqrt{K(X_i, X_i) - 2K(X_i, W_j) + K(W_j, W_j)}$$
$$= \sqrt{2 - 2K(K_i, W_j)}$$

Introduce kernel function in FCM and minimize objective function $J_{km.}$

$$J_{km}(U, W) = 2\sum_{j=1}^{c}\sum_{i=1}^{N} U_{ij}^{m}\left(1 - K(X_i, W_j)\right) \quad (8)$$

Objective function j_m describe a constrained optimization problem, which can be changed to an unconstrained optimization problem by using Lagrange multiplier technique. By using this calculates membership function and update cluster center separately

$$U_{ij} = \frac{\left(1-K(x_i,w_j)\right)^{-\frac{1}{m-1}}}{\sum_{k=1}^{c}\left(1-K(x_i,w_j)\right)^{-\frac{1}{m-1}}} \quad (9)$$

Calculate cluster center using following step

$$W_j = \frac{\sum_{i=1}^{N} u_{ij}^{m} K(x_i,w_j) x_i}{\sum_{i=1}^{N} u_{ij}^{m} K(x_i,w_j)} \quad (10)$$

Algorithm:

J_{km} can be obtain through an iterative process, which is achieved by following steps

INPUT

1. $X=\{X_1, X_2 \ldots. X_N\}$, Data set
2. C, $2\leq C\leq n$, n is number of cluster
3. Set value of Ɛ, it is stopping criteria parameter
4. Initialize membership function U_{ij}^{0} using data set and cluster.
5. Calculate initial cluster center $W_0= (w_{01}, w_{02} \ldots w_{0c})$

OUTPUT

$W_j = \{W_0, W_1, W_2 \ldots\ldots W_j\}$, Final center of clusters.

Step:

1. Set loop counter p=0
2. Calculate C cluster center W_j^{p} with U^{p} by using equation (10)
3. Calculate membership function U^{p+1} by using equation. (9).
4. If $\{U^{p} - U^{p+1}\} < \varepsilon$, then stop otherwise set p=p+1 and go to step 2.

KFCM it work properly in noisy image but KFCM not focus on neighborhood term.

E. Novel Modified Kernel fuzzy c-Means Algorithm (NMKFCM)

Novel modified kernel fuzzy method is assimilating neighborhood pixel value in objective function. Novel modified kernel fuzzy c-means algorithm is modified version of KFCM. NMKFCM which incorporate neighborhood pixel value using 3×3 or 5×5 window and introduce this value in objective function[10][1]. In this '∝' parameter is used to control effect of neighbor's term which is getting higher value with increase of image noise. Range of ∝ value lies within 0 to 1, if percentage of noise is low then choose value of ∝ between 0 and 0.5 and percentage of noise is higher then choose value of ∝ 0.5 and 1.0. NMKFCM is an iterative process which minimizes value of objective function with neighborhood term[11]. In this objective function introduce window around pixel and ∝ parameter.

$$J_{nmkm}(U,W) = \sum_{j=1}^{c}\sum_{i=1}^{N} u_{ij}^{m}\left(1-K(x_i,w_j)\right)\left(\frac{N_R - \alpha\sum_{k\subset N_i} u_{jk}}{N_R}\right) \quad (10)$$

Where:N_R: The cardinality, N_i: Set of neighbors falling into a window around pixel $X_{i,,}$

Objective function j_{nmkm} describe a constrained optimization problem, which can be converted to an unconstrained optimization problem by using Lagrange multiplier technique. By using this calculates membership function and update cluster center separately.

$$U_{ji} = \frac{\left(\left(1-K(X_j,W_j)\right)\left(\frac{N_R-\alpha\sum_{l\subset N_l}U_{jl}}{N_R}\right)\right)^{-\frac{1}{m-1}}}{\sum_{k=1}^{C}\left(\left(1-K(X_i,W_j)\right)\left(\frac{N_R-\alpha\sum_{l\subset N_l}U_{jl}}{N_R}\right)\right)^{-\frac{1}{m-1}}} \quad (11)$$

And calculate cluster center using following step.

$$W_j = \frac{\sum_{i=1}^{C} U_{ji}^m K(X_i,W_j)X_i}{\sum_{i=1}^{N} U_{ji}^m K(X_i,W_j)} \quad (12)$$

Algorithm:

J_{nmkm} can be obtain through an iterative process, which is achieved by following steps

INPUT

1. X={X_1, X_2….X_N}, Data set
2. C, 2≤C≤n, n is number of cluster
3. Set value of Ɛ, it is stopping criteria parameter
4. Initialize membership function U_{ij}^0 using data set and cluster.
5. Calculate initial cluster center W_0= (w_{01}, w_{02}…w_{0c})

OUTPUT

W_j = {W_0, W_1, W_2……W_j} , Final center of clusters.

Step:

1. Set loop counter p=0
2. Calculate C cluster center W_j^p with U^p by using equation (12)
3. Calculate membership function U^{p+1} by using equation. (11).
4. If $\{U^p - U^{p+1}\} < \varepsilon$, then stop otherwise set p=p+1 and go to step 2.

III.Hill-climb algorithm

Image segmentation is a very important part of image processing. Detection of salient image regions is useful for applications like image segmentation, adaptive compression and region –based image retrieval. Saliency is determined as the local contrast of an image region with respect to its neighborhood at various scales [12]. For finding salient regions uses a contrast determination filter that operates at various scales to generate saliency maps containing saliency values per pixel.

In this evaluate distance between the average feature vectors of the pixel of an image sub-region with average feature vector of the pixels of its neighborhood. At a given scale, the contrast based saliency value $c_{i,j}$ for a pixel at position (i, j) in the image is determined as the distance D between the average vectors of pixel features of the inner region R1 and that of the outer region R2.

$$c_{i,j} = D\left[\left(\frac{1}{N_1}\sum_{p=1}^{N_1} v_p\right),\left(\frac{1}{N_2}\sum_{q=1}^{N_2} v_q\right)\right] \quad (13)$$

Where N1 and N2 are the number of pixels in R1 and R2 respectively, and v is the vector of feature elements corresponding to a pixel. The distance D is a Euclidean distance if v is a vector of uncorrelated feature elements, and it is a Mahalanobis distance if the elements of the vector are correlated. In this work, CIELab color space, assuming RGB images, to generate feature vectors for color and luminance. Since perceptual differences in CIELab color space are approximately Euclidian, D in equation (13).

$$c_{i,j} = \|v1 - v2\| \quad (14)$$

Where v1 = [L1; a1; b1]T and v2 = [L2; a2; b2]T are the average vectors for regions R1 and R2, respectively. The final saliency map is calculated as a sum of saliency values across the scales S:

$$m_{i,j} = \sum_s c_{i,j} \quad (15)$$

The hill-climbing algorithm can be seen as a search window being run across the space of the d-dimensional histogram to find the largest bin within that window.

Algorithm:

1. Find the color histogram of image.

2. Starting with non zero bin , the uphill move is made if the number of pixels in the current bin is different from other bins towards the bin with greater number of pixels and we continue it till we find no neighboring bin with larger number of pixels.
3. These initial peaks are the number of clusters.
4. Neighboring pixels that lead to the same peaks are grouped together

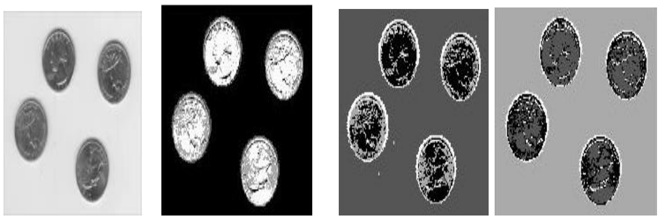
IV.Experimental Result

NMKFCM method is performing segmentation on real image, medical image and synthetical image. NMKFCM method is improved result of image segmentation as compare to FCM and KFCM. Three types of parameter are used to evaluate the performance of NMKFCM method like CAR, Runtime and Number of iteration.

All experiments were run on a computer with Intel Celeron processor M 1.7 GHz, 512-MB memory, the OS is Microsoft Windows XP, and the plat is MATLAB 6.5. To evaluate performance of the clustering algorithms, we use Clustering Accuracy Rate(CAR) which is defined

$$CAR = \left| \frac{A_{ij} \cap A_{refj}}{A_{ij} \cup A_{refj}} \right| \tag{16}$$

Where A_{ij} is represent the set of pixel belonging to j^{th} class found by i^{th} algorithm and A_{refj} represent the set of pixel belonging to the j^{th} class in the reference segmented image. By using this formula calculate accuracy rate.
Experiment I(Real Image): We apply three fuzzy clustering algorithms to real image and Add 2%,5% and 10% salt and pepper noise into real image. Hill-climbing algorithm automatically determines cluster number 13 is used in image segmentation



(a) (b) (c) (d)

Fig. 1: Real image without noise (a) Real Image (b) FCM (c) KFCM (d) NMKFCM

Table 1: Comparison with fuzzy clustering algorithms using Cluster Accuracy Rate

% NOISE	FCM	KFCM	NMKFCM
0%	68.3671%	70.2319%	74.3112%
2%	72.1148%	72.5515%	80.2062%
5%	61.4426%	84.6165%	91.763%
10%	61.1302%	77.6205%	83.4534%

In all cases, NMKFCM has improved accuracy rate as compare to other fuzzy clustering algorithms.
In NMKFCM choose ∝ value from 0 to 0.5 for less noisy image and for noisier image choose ∝ value from 0.5 to 1, N_R=8.

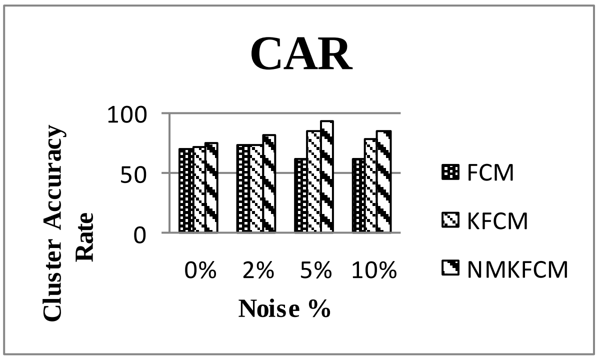


Fig. 2: Comparison between fuzzy clustering algorithms using Cluster Accuracy Rate

Table 2: Runtime for Real image without noise

Method	Runtime In Second
FCM	4.2755 sec
KFCM	5.2075 sec
NMKFCM	4.2084 sec

Experiment II(Medical Image): We apply three fuzzy clustering algorithms to medical image and Add 2%,5% and 10% salt and pepper noise into real image. Hill-climbing algorithm automatically determines cluster number 17 is used in image segmentation for noiseless image.

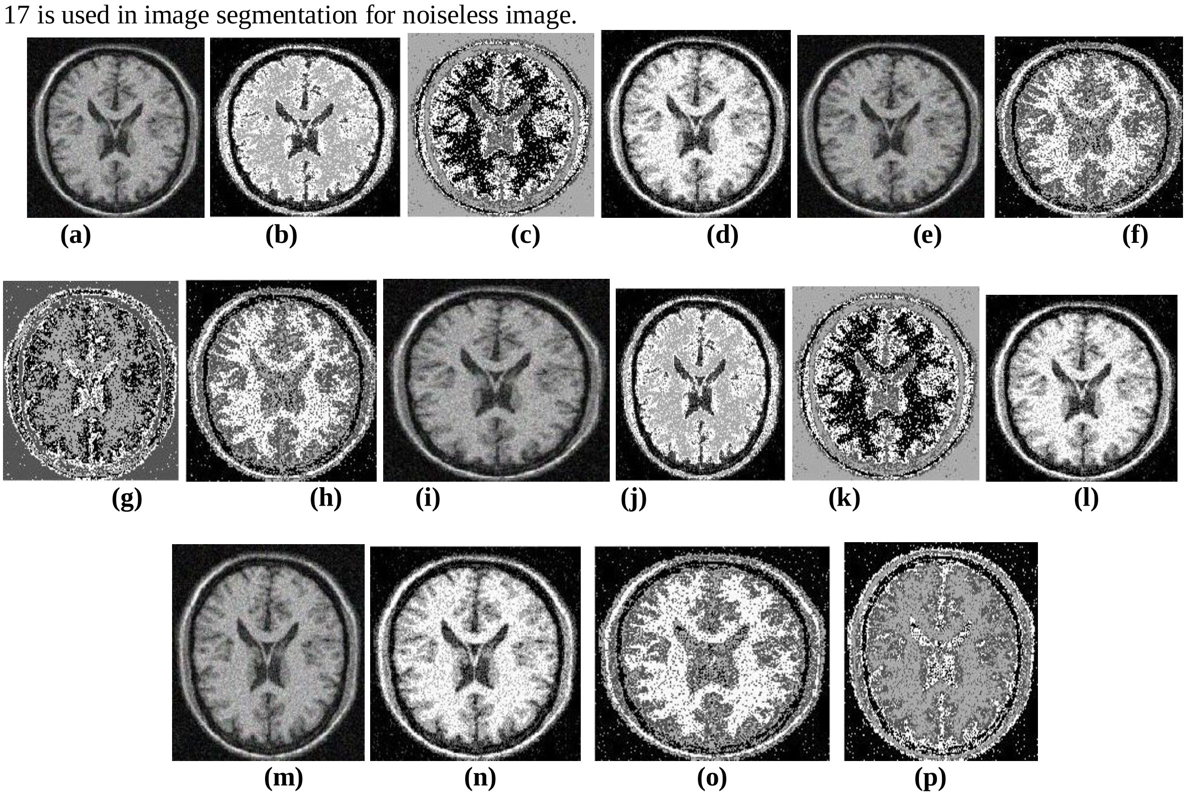


Fig.3:(a) Medical Image (b) FCM, (c) KFCM (d) NMKFCM (e) 2% Gaussian noise medical image (f)2% Noise FCM (g)2% Noise KFCM (h)2% Noise NMKFCM,(i)5% Gaussian Noise Medical Image (j)5% Noise FCM (k)5% Noise KFCM (l)5% Noise NMKFCM (m)10% Gaussian Noise Medical image,(n)10% Noise FCM,(o)10% Noise KFCM,(p)10% Noise NMKFCM

In fig.3(a) noiseless medical image, we required number of cluster is 17 which is calculated with help of Hill-climb algorithm. In NMKFCM choose $\propto$ value from 0 to 0.5 for less noisy image and for noisier image choose $\propto$ value from 0.5 to 1, N_R=8.

Table 3: Comparison between FCM, KFCM and NMKFCM using CAR

Noise %	FCM	KFCM	NKFCM
0%	70.7439%	68.6309%	72.0572%
2%	70.4721%	69.5362%	72.6506%
5%	69.8048%	73.467%	76.0044%
10%	75.6375%	69.6031%	75.7221%

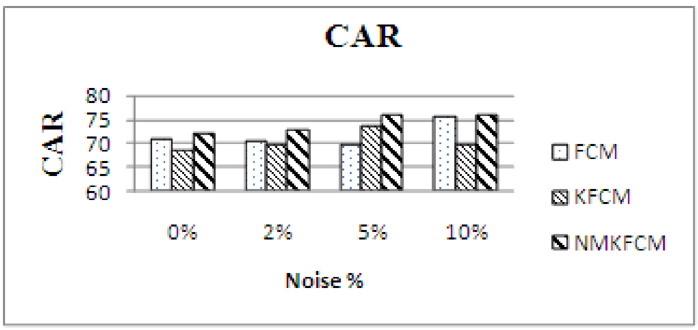


Fig.4: Comparison between FCM, KFCM, and NMKFCM using CAR value Table III

V.**Conclusion**

Proposed algorithm gives efficient image segmentation than FCM and KFCM fuzzy clustering algorithms. Proposed method improves the segmentation performance by incorporating the effect of neighbor pixel information.. Proposed algorithm has determined automatically required cluster number for image segmentation. There are several things that could be done in the future as the continuation of this work. At firstly, in noisy image propose algorithm which can be determined automatically cluster number but this number is not useful for image segmentation because proposed algorithm has been generated cluster for noisy pixel so image segmentation could not be effective as compare to noiseless pixel. Secondly choosing of optimal parameter α is still an important issue, proposed algorithm assign value of optimal parameter α randomly.

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