# APPLICATION OF VARIOUS SEGMENTATION TECHNIQUES FOR BRAIN MRI –A COMPARATIVE STUDY

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## ABSTRACT

*In this paper, the segmentation of magnetic resonance brain (MR) images has been analysed using K-Means clustering, Fuzzy C-Means clustering (FCM) and Pulse Coupled Neural Network (PCNN) techniques. All the three methods are applied to normal and abnormal brain MR images and the results are compared for accuracy and time span. This paper includes pre-processing, segmentation and accuracy evaluation stages. The real brain MR images are segmented into gray matter, white matter, cerebro - spinal fluid and background regions in the case of normal images and tumor region in the case of abnormal image. The results of the current work show that the FCM technique is more promising than the other two methods.*

***KEYWORDS**:* MRI real brain images, Image segmentation, K-Means, Pulse Coupled Neural Network (PCNN), Fuzzy C-Means clustering (FCM).

## I. INTRODUCTION

The interesting tissues in brain are white matter(WM), gray matter(GM), and cerebro-spinal fluid (CSF). The changes in the composition of these tissues in the whole volume or within specific region may lead to various diseases. Hence, it is very much important to estimate the size of each tissue accurately for proper treatment. Fuzziness is the inherent characteristic of medical images, So, FCM technique can be easily applied to them. As the pixels are partially classified into multiple classes, it can recover a lot of information from the original image than other segmenting methods. J.F. Lu*etal.*[1] focussed on adaptation of hierarchical structure to find the cluster centers, that can be used for initializing K-Means algorithm. Dongxiang Chi[2] proposed a new method for extracting color image features trained by SOM neural network then clustered by K-Means accompanied with the guidance of entropy based image segmentation technique. M.Masroor Ahmed *et al.*[3]described an efficient method for the automatic extraction of brain tumor tissues by combining perona and Malik anisotropic diffusion model with K-Means clustering technique. S. Sathishkumar *et al.*[4] proposed an improved method to segment the brain magnetic resonance image (MRI) data by combining neuro-fuzzy technique and compared the results with K-Means and fuzzy clustering techniques. Veronica S. Moertini [5] gave an introduction of five data clustering algorithms including K-Means and Fuzzy C-Means clustering techniques. Yang gefeng *et al*. [6] did a research based on fuzzy clustering method for medical image segmentation including spatial information. Eghbal G. Mansoori [7] employed a supervised classification approach to do the unsupervised cluster analysis based on a novel fuzzy rule-based classifiers. Kuntimad granganath H.S[8] explained well about the image segmentation process using Pulse Coupled Neural Network. Gu Xiaodong *et al.*[9]proposed a new approach for deducting the edges in images using Pulse Coupled Neural Network. In this paper, K-Means, Fuzzy C-Means clustering and Pulse Coupled Neural Network techniques have been analysed using brain magnetic resonance image data and the results were compared. The Schematic representation of the proposed work is shown in figure 1.

The rest of the paper is given as follows, section 2 gives the basic concept of K-Means clustering. The detailed description of FCM method is given in section 3. Section 4 demonstrates the PCNN model and the technique. The results of three methods are analysed in section 5. This paper has been concluded in section 6.

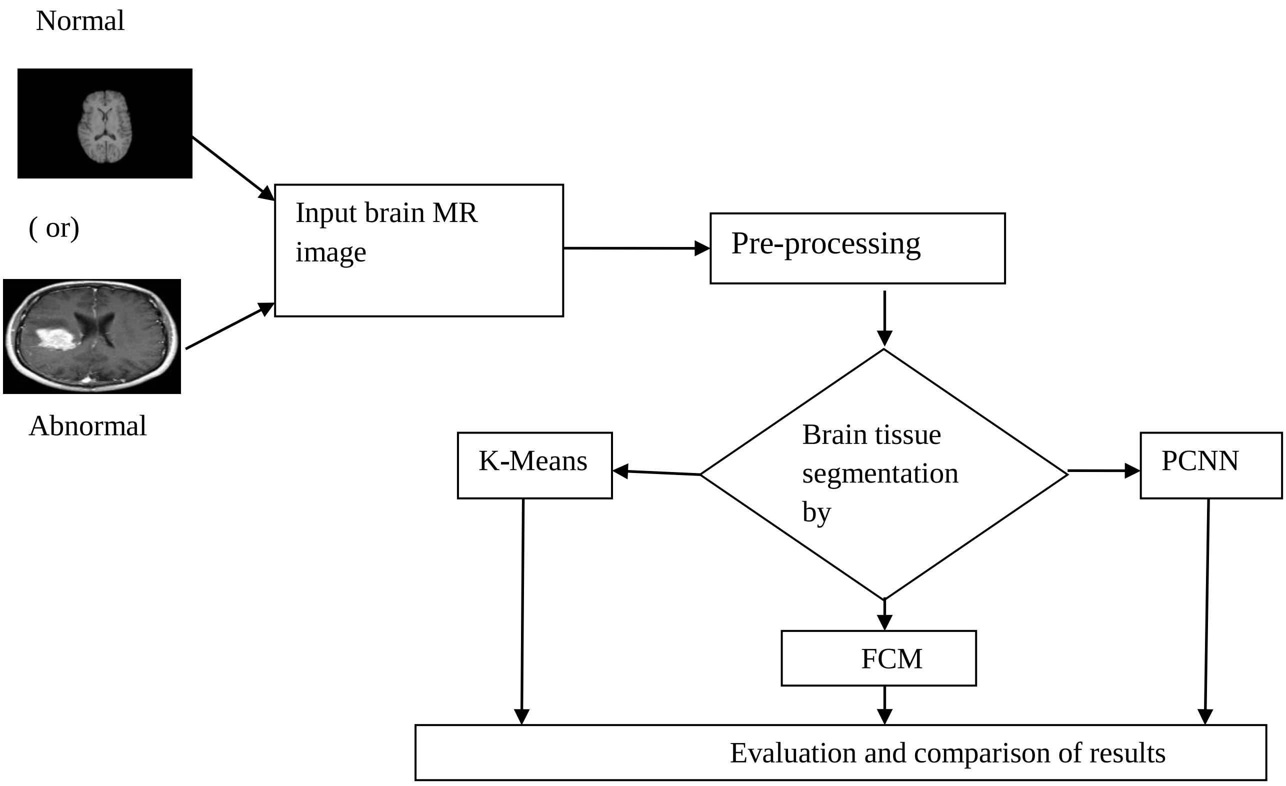


**Figure 1.**Methedology of Proposed Work

## II. K-MEANS CLUSTERING

K-means clustering is one of the simplest methods and has low computational complexity. It is an unsupervised method applied to bio-medical image segmentation process when the number of clusters are well known depending upon the regions of human anatomy [10]. The procedure for clustering technique is as follows:

### 2.1 K-Means Clustering Algorithm

1. Cluster centers are initialized.
2. The data set is partitioned into K clusters and the data points are randomly assigned to the clusters.
3. For each data point, calculate the Euclidean distance from the data point to the mean of each cluster.
4. If the data point is not closest to its own cluster, shift it to the closest cluster.
5. If the data point is already closest to its own cluster, don't shift it.
6. The process continues until cluster mean don't shift more than a given cut-off value or the iteration limit is reached.

## III. FUZZY C-MEANS CLUSTERING

In most of the clustering algorithms fuzzy clustering plays an important role in an image segmentation. In fuzzy clustering, fuzzy c-means algorithm is the most effectual algorithm. An evaluation criterion is needed in the form of an objective function to distinguish the correct solution from the numerous possible solutions. The standard fuzzy c-means objective function is given in [11] as in the following equation (1),

$$Jfcm = \sum_{i=1}^{c} \sum_{j=1}^{n} u_{ij}^{m} \left\| x_j - c_i \right\|^2 \quad (1)$$

Where 'c' is the number of clusters; $c_i$ is the cluster center; and m is the weighing exponent. $u_{ij}$ is the membership function. The updation of membership ($u_{ij}$) and cluster center ($c_i$) is given by,

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

$$c_i = \frac{\sum_{i=1}^{n} u_{ij}^{m} x_j}{\sum_{j=1}^{n} u_{ij}^{m}} \quad (3)$$

In image clustering , the gray level value or the intensity of the image pixel is the most commonly used feature. Hence, the objective function of FCM should be minimized in such a way that pixel intensities close to the the centroid of a particular class are assigned with high membership values , and the pixels that are far from the centroid are assigned with low membership values.

### 3.1 Fuzzy C-Means Algorithm

1. Get the data from the image.
2. Select the number of clusters and initialize the centroid.
3. Compute the membership and update it by using Equation (2).
4. Update the centroid of the clusters by using Equation (3).
5. Repeat the steps 3&4 until the following termination criterion is satisfied:

$$\left\| u_{ij}^{t+1} - u_{ij}^{t} \right\| < \varepsilon$$

Where $\|.\|$ is the Euclidean norm and $\varepsilon$ is small number (0.01) which can be fixed during the initialization process.

## IV. PULSE COUPLED NEURAL NETWORK TECHNIQUE

The Pulse Coupled Neural Network technique is explained as follows,

### 4.1 PCNN model

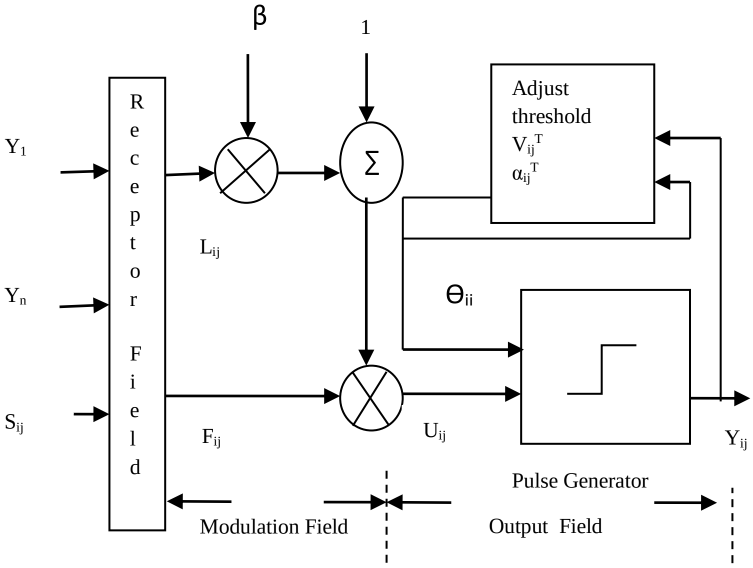


**Figure 2. Pulse Coupled Neuron Model**

The figure 2 shows the model of Pulse Coupled Neuron. It has three fields, Receptor field, Modulation field and output field[12,13]. The receptor field has two channels- L-linking channel and F- feeding channel. The feeding channel is fed directly by an external source, which is the image pixel intensity connected to the neuron. The linking channel is fed by other neurons called neighbouring neurons to the feeding channel neuron. The linking channel time constant is lower than feeding channel. The total number of input neurons will be the same as the total number of image pixel intensities. There is one -to – one correspondence between the input neurons and the image pixels. Each neuron is linked with its neighbouring neurons by linking strength (β).
The modulation field gets input signals from the feeding and linking channels. In the modulation field, the linking channel neurons are added together and multiplied with the linking strength and then biased with the unit value. The output is multiplied with the feeding channel output to produce the internal activation function($U_{ij}$) which is the output of the modulation field. The output field consists of one pulse generator block and one threshold signal block. The activation function ($U_{ij}$) is compared with the threshold($\theta_{ij}$).When $U_{ij}$ is greater than $\theta_{ij}$ ,The output($Y_{ij}$) sets to '1'. The output is given to the threshold signal block, the value of $\theta_{ij}$ increases and causes the output($Y_{ij}$) to become '0' by making $\theta_{ij}$ greater than $U_{ij}$, then $\theta_{ij}$ decays automatically having the value lesser than $U_{ij}$. Thus the output '$Y_{ij}$' generates the step function for each iteration. The constants are given as $\alpha_F$=0.001,$\alpha_L$= 1.00, $\alpha_\Theta$ = 0.2, $V_F$ = 0.01, $V_L$ = 1.00, $V_\Theta$ = 20, β = 3. The parameters are given by the following equations.

$$F_{ij}(n) = e^{-\alpha_F} F_{ij}(n-1) + S_{ij} + V_F \sum_{kl} M_{ijkl} Y_{kl}(n-1) \quad (4)$$

$$L_{ij}(n) = e^{-\alpha_L} L_{ij}(n-1) + V_L \sum_{kl} W_{ijkl} Y_{kl}(n-1) \quad (5)$$

$$U_{ij}(n) = F_{ij}(n)(1+\beta L_{ij}(n)) \quad (6)$$

$$\theta_{ij}(n) = e^{-\alpha_\theta}\theta_{ij}(n-1) + V_\theta Y_{ij}(n-1) \quad (7)$$

$$Y_{ij}(n) = \begin{cases} 1 & U_{ij}(n) > \theta_{ij}(n) \\ 0 & U_{ij}(n) \le \theta_{ij}(n) \end{cases} \quad (8)$$

Where, $M_{ijkl}$, $W_{ijkl}$ are weighing factors, $\alpha_F$, $\alpha_L$,$\alpha_\theta$ are decaying time constants, $V_F$,$V_L$,$V_\theta$ are inherent electric potential. '$F_{ij}$' is feeding input, '$L_{ij}$' is linking input, '$U_{ij}$ 'internal activation function, '$\theta_{ij}$' is threshold signal, 'β' is the linking strength and 'n' is the number of iterations. The linking strength'β' should be such that, to cover the points in the required area and to eliminate the points in the outer area.

### 4.2 PCNN Proceeding Steps:

1. Initialize the parameters.
2. Initialize the total number of iterations $n_{max}$ =20.
3. For each iteration, calculate the equations 4-8 and n=n+1.
4. If n< $n_{max}$, repeat the step 3, Otherwise output $y_{ij}$.

## V. RESULT INTERPRETATION

The real T1 and T2 weighted brain MR images of size 1mm thickness have been collected from the department of Radiology, Raja Muthaiya Medical College and Hospital (RMMCH), Annamalai university, India. The three segmentation methods are applied over the images, and the results were analysed. Before segmentation, the images have been pre-processed by using a median filter, a window of size 3x3 is selected, and it is moved over the entire image to include the information about the spatial neighbour-hood. The three different tissues (i.e., gray matter, white matter and cerebro - spinal fluid) and the background are divided into different intensity levels. The partition of brain tissues resulting from the above methods were validated against the manual segmentation of the image with the same pixel strength and thickness, which is a pixel based evaluation. The accuracy of the segmentation results has been calculated based on the terms TP,TN,FP,FN[14,15,16].

TP : True positive, object pixels that are correctly classified as an interest object.
TN : True negative, background pixels that are correctly identified as background
FP : False positive, background pixels that are incorrectly identified as an interest object.
FN : False negative, object pixels that are incorrectly identified as background.

Sensitivity and Specificity are the statistical measures, sensitivity measures the proportion of actual tissue pixels that are correctly identified as such. Specificity measures the proportion of background pixels that are correctly identified as background.

The statistical measures and accuracy are given by,

(i) Sensitivity $= \frac{TP}{TP+FN}$ (9)

(ii)Specificity $= \frac{TN}{TN+FP}$ (10)

(iii)Accuracy$= \frac{(TP+TN)}{(TP+TN+FP+FN)}$ (11)

The results of the three methods for normal and abnormal images are shown in figure 3 and 4 respectively.

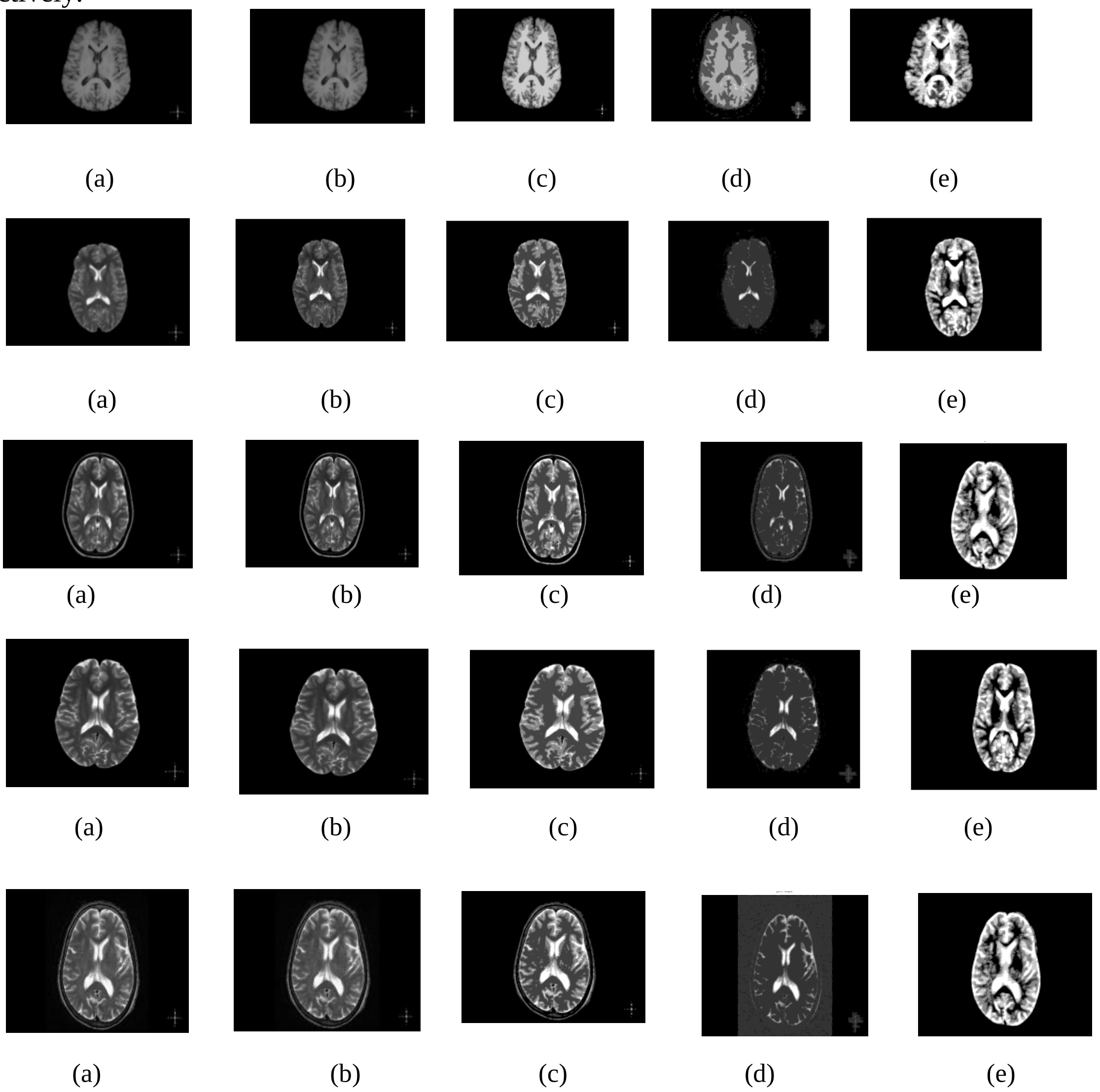


**Figure 3 -** (a). Five normal real input images, (b). Median filtered images, (c). FCM output, (d). PCNN output, (e). K-Means output.

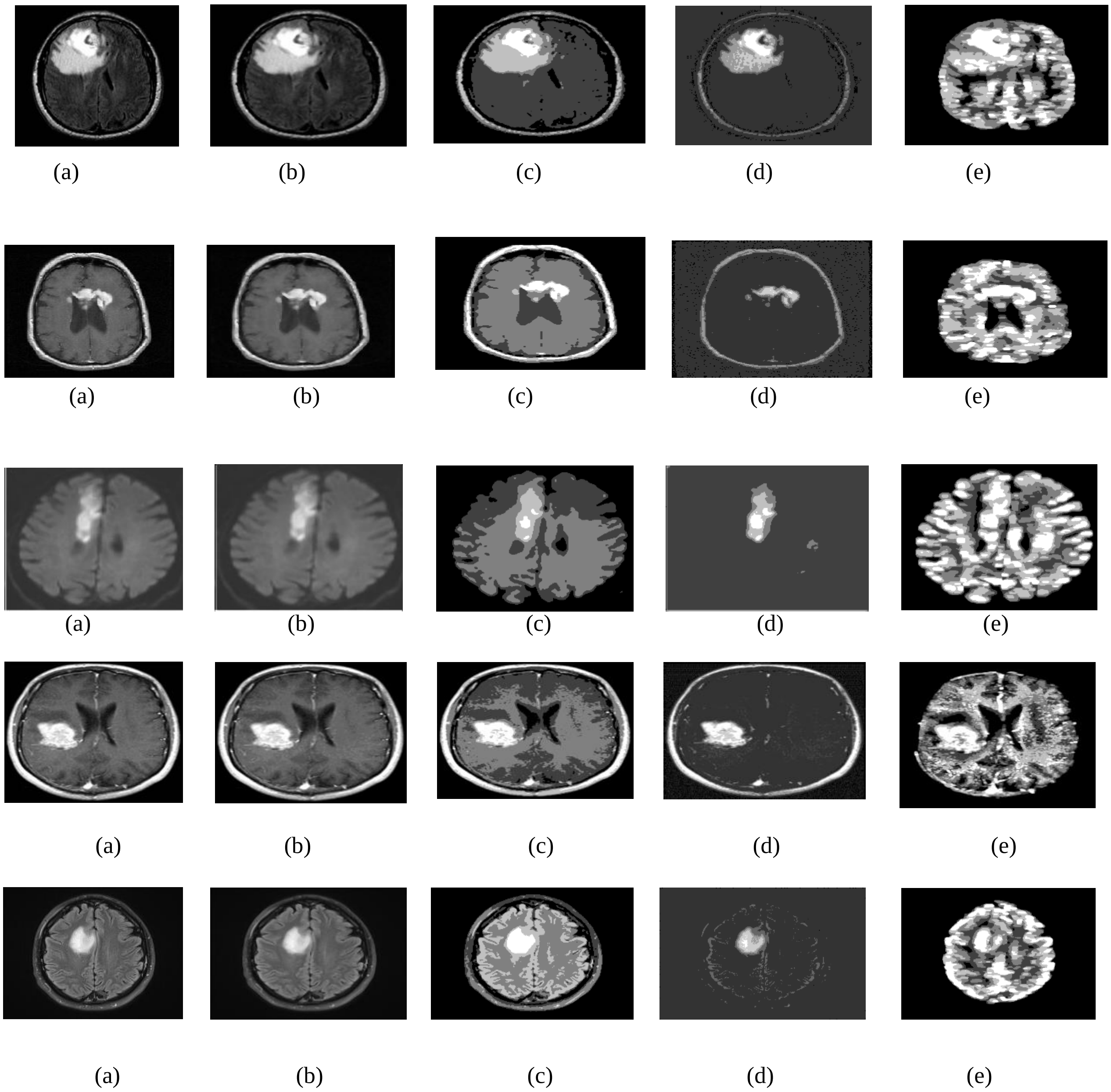


**Figure 4-** (a). Five abnormal real input images, (b). Median filtered images, (c). FCM output, (d). PCNN output, (e). K-Means output.

Table 1 gives the details of the accuracy values of five normal real images. Table 2 shows the accuracy values of five abnormal real images.Figure 5 is the overall accuracy chart for five normal cases and figure 6 is the overall accuracy chart for five abnormal cases.

**Table 1**Accuracy Values for Five Normal Images.

| Normal images | FCM | K-Means | PCNN |
|---|---|---|---|
| 1 | 98.33 | 56.88 | 93.86 |
| 2 | 97.17 | 57.63 | 88.52 |
| 3 | 95.1 | 54.34 | 90.48 |
| 4 | 96.62 | 60.52 | 92.62 |
| 5 | 92.48 | 63.86 | 89.24 |
| Average accuracy | 95.94 | 58.646 | 90.944 |

**Table2** Accuracy Values for Five Abnormal Images.

| Abnormal images | FCM | K-Means | PCNN |
|---|---|---|---|
| 1 | 95.36 | 55.63 | 95.559 |
| 2 | 93.86 | 51.02 | 97.59 |
| 3 | 94.69 | 61.3 | 98.02 |
| 4 | 96.37 | 45.39 | 97.53 |
| 5 | 95.68 | 50.08 | 91.89 |
| Average accuracy | 95.192 | 52.684 | 96.118 |

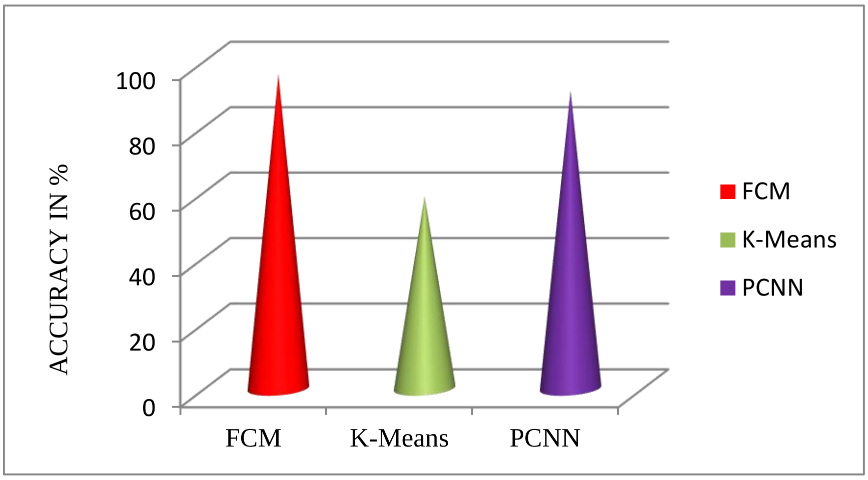


**Figure 5.**Average accuracy plot for Five Normal Images.

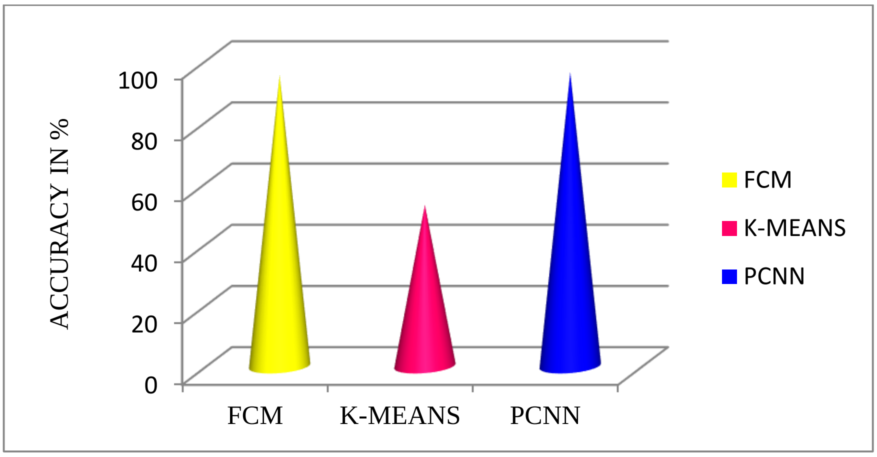


**Figure 6.** Average accuracy plot for Five Abnormal Images.

It is observed from table1and 2 that the average accuracy value for normal case in K-Means clustering is around 58.65%,in PCNN 90.94%,in FCM 95.94% and in abnormal case 52.68% for K-Means clustering , 96.12% for PCNN, 95.19% in Fuzzy C-Means clustering technique.From the above facts, it is obvious that FCM method shows promising and encouraging results in the current study.

## VI. CONCLUSION

This paper focuses a comparative analysis of three different types of segmentation techniques. It includes K-Means clustering, Fuzzy C-Means clustering and Pulse Coupled Neural Network segmentation methods. In accordance with the comparison of results, this paper concludes that the major drawbacks of k-means clustering technique are that it gives high value of misclassified data after segmentation process and also it is time consuming. Though the PCNN technique has also high value of accuracy, it is also time consuming and has computational complexity. Hence, the present paper clearly shows FCM clustering is more accurate and less time consuming. Future work will focus on improving the segmentation accuracy through feature extraction and extending the Fuzzy C-Means clustering segmentation process to include bias correction and kernel functions.

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