Performance Analysis of Advanced Image Segmentation Techniques

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ABSTRACT
Image segmentation remains one of the major challenges in image analysis, since image analysis tasks constrained by how well previous image segmentation is accomplished. It is considered as an important basic operation for meaningful analysis and interpretation of acquired images. In most of the image processing applications 'clustering algorithm' is used as the segmentation method, because clustering algorithm can segment and determine certain regions of interest in a particular image. During image acquisition, images will be affected by salt-and-pepper noise and this will affect further processing result of the image. For obtaining a better segmented image from a noisy image, a new method is proposed. In this new method (clustering algorithm), noise detection stage is included to the existing clustering algorithms like k-means, fuzzy c-mean, etc., In this method, the correction value for the noise pixel is found and this value is used to replace the noise pixel value in the corrupted image. By doing like this, the effect of noise can be reduced. Then the clustering technique is applied for segmenting the image. After segmentation, the segmented image is analyzed both qualitatively and quantitatively.

Keywords
Clustering, Image segmentation, salt-and-pepper noise, image processing.

1. INTRODUCTION
Generally, image segmentation is defined by the most of scientists as partitioning an image into separate regions which are homogeneous with respect to some characteristics such as gray level, texture etc. These homogeneous characteristics of the images are the major challenges in image analysis. Image segmentation is considered as the basic operation for meaningful analysis and interpretation of acquired images. Different techniques are available for segmenting an image into separate regions. Each of these segmentation techniques will be suitable for a particular type of image and segmentation depends on the type of image. The segmentation techniques can be broadly classified into two categories. They are 1) classical and 2) fuzzy mathematical [1].

The classical segmentation type includes five main classes. They are a) Gray level thresholding b) Iterative pixel classification c) Surface-based segmentation d) Color segmentation e) Edge detection and the fuzzy mathematical type includes 1) fuzzy clustering 2) fuzzy rule 3) fuzzy geometry 4) fuzzy thresholding and 5) fuzzy integral. Fuzzy image segmentation techniques can segment noisy images by using fuzzy membership values. They are advantageous over classical methods as they can handle imprecise data. [2]

Two different approaches may be used for segmenting images with intensity in homogeneities. In the first approach, a correction algorithm is separately applied for removing intensity in homogeneities and then the segmentation algorithm is applied. The advantage of the clustering algorithm approach is that once the image has been corrected, the intensity in homogeneities can be ignored in subsequent processing. In the second approach, segmentation algorithm is directly applied on the image with intensity in homogeneities. Here, shading effect will be compensated along with segmentation of the image. The advantage of this approach is that intermediate information can be used.

In this paper, it is elaborated how the segmentation is applied directly on the noisy image. There is no need to apply separate correction algorithm before segmenting the image. In this paper, salt-and –pepper noise is considered for the research.

2. 2. PRELIMINARIES

2.1. Salt-and-pepper Noise
Impulse noise is caused by the transmission through noisy channels, malfunctioning pixels in camera, or faulty memory locations in the hardware. There mainly two types of impulse noises. They are 1) Salt-and-Pepper noise 2) Random valued noise. Salt-and Pepper noise can have intensity values only in the maximum and minimum range. For an 8-bit gray level image corrupted with salt-and-pepper noise , the noise pixels can take only intensity values 0 and 255.Intensity values 0 indicates black or pepper and the intensity value 255 indicates white or salt. The salt and pepper noise appears as black and white spots scattered on the image. [2]

2.2. Segmentation
Segmentation subdivides an image into constituent regions or objects. For monochromatic images, segmentation algorithms are based on the gray level image properties like discontinuity and dissimilarity.

There are many image segmentation techniques based on clustering. Clustering is the process of grouping data samples with similar characteristics into one group for further analysis. Each cluster will have one center also called as cluster centroid. The grouping is based on some measures like Euclidean distance. Some segmentation technique uses hard clustering and some uses fuzzy clustering approaches.

In hard clustering sharp boundaries are assumed between the clusters. Also an object belongs to only one cluster. One of the most commonly used hard clustering algorithms is k-means clustering algorithm. [3] In fuzzy clustering, overlapping of clusters is considered. A data can belong to more than one cluster. A membership values is given to each to indicate the degree of belonging to a particular cluster. A membership value varies between 0 and 1. A membership value of 1 indicates that the object belongs to that cluster only. A membership value of 0 indicates that the data does not belong to that cluster. The most commonly used fuzzy clustering algorithm is fuzzy c-means (FCM) algorithm. It assigns a data to more than one cluster.[3]

Clustering based segmentation is applied in medical field specifically in biomedical image analysis [12]-[15]. It is capable of segmenting and determining the number of regions in the segmented image.

2.3. Binary Noise Mask

Binary mask is a binary image that has the same size as that of the original image. In the binary noise mask, pixels that are corrupted by noise will be set to 1 and all the remaining pixels are set to zero.

In the case of images corrupted with salt-and-pepper noise ,those pixels which are having the intensity value either 0 or 255 will be set to 0 in the mask and remaining pixels are set to 1.

3. CONVENTIONAL CLUSTERING METHODS

In this paper, two clustering algorithms are considered .The two clustering techniques are

1) K-Means Clustering Algorithm

2) Fuzzy C-Means Clustering Algorithm

3.1. K-Means Clustering Algorithm

K-Means algorithm is probably one of the first clustering algorithms proposed and is based on a very simple idea. The main idea is to define k centroids, one for each cluster. These centroids should be placed in a cunning way because of different location causes different result. So, the better choice is to place these centroids as much as possible far away from each other. The next step is to take each point belonging to a given data set and associate it to the nearest centroid. When no point is pending, the first step is completed and an early group age is done. At this point it is necessary to re-calculate k new centroids as bar centres of the clusters resulting from the previous step. After obtaining these k new centroids, a new binding has to be done between the same data set points and the nearest new centroid. A loop has been generated. As a result of this loop, one may notice that the k centroids change their location step by step until no more changes are done. In other words centroids do not move any more. Finally, this algorithm aims at minimizing an objective function; in this case a squared error function. The objective function of k-means clustering algorithm is given by [8]

$$J = \sum_{k=1}^{n_c} \sum_{t=1}^{N} \left\| v_t - c_k \right\|^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where N is the number of data to be clustered into n_c regions, c_k is the k^{th} centre and v_t is the t^{th} data point. $\|\cdot\|$ stands for a distance measure that is normally taken to be the Euclidean norm. All data will be assigned to the nearest centre based on the Euclidean distance. The new centroid is calculated using the equation

$$c_k = \frac{1}{n_{c_k}} \sum_{t \in c_k} v_t \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

The K-Means clustering algorithm has many advantages. It is simple to understand, easy to code and is scalable and efficient. In spite of the above mentioned advantages it has the following disadvantages.[1]-[3]

1) It can be slow; since in each step Euclidean distance has to be calculated. This will take more time when the data set becomes large.

2) The algorithm greatly depends on the initial cluster centers

3) The algorithm is sensitive to outliers and skewed distribution.

3.2. FCM clustering Algorithm

FCM algorithm is introduced by Bezdek and is one of the most commonly used clustering algorithms. This is because it can retain much more information than hard clustering algorithms. With the use of fuzzy theory in FCM, one piece of data can belong to more than one cluster. It is based on minimization of the objective function. The objective function of FCM is calculated using the equation [9]

$$J = \sum_{k=1}^{n_c} \sum_{t=1}^{N} \left(M_{kt}^{m} \right) \left\| v_t - c_k \right\|^2 \quad \ldots\ldots\ldots(3)$$

Where M_{kt}^{m}, is the fuzzy membership function and m is the fuzziness exponent. It is an integer, $m > 1$.The membership function represents the probability that a pixel belongs to a particular cluster. The probability depends only on the distance between pixel and each individual cluster center. With fuzzy *c*-means, the centroids of a cluster are computed as being the mean of all points, weighted by their degree of belonging to the cluster. The degree of being in a certain cluster is related to the inverse of the distance to the cluster. By iteratively updating the cluster centroids and the membership grades for each data point, FCM iteratively moves the cluster centroids to the right location within a data set. The new position for each centroid is calculated using the equation

$$c_k = \frac{\sum_{t=1}^{N} \left(M_{kt}^{m} \right) v_t}{\sum_{t=1}^{N} M_{kt}^{m}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The fuzzy membership function is given by the equation

$$M_{kt}^{m} = \frac{1}{\sum_{t=1}^{n_c} \left(\frac{d_{kt}}{d_{lt}} \right)^{\frac{2}{m-1}}} \;, \; if \quad d_{lt} > 0, \forall\, l, t \quad \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Where $d_{kt} = \|v_t - c_k\|^2$ is the Euclidean distance between t^{th} data point and k^{th} cluster centre. These steps are repeated until the difference in the membership functions of successive iteration differ by a predefined value called termination criteria.

The main advantage of this method is that it does not require prior knowledge about the cluster centers. But FCM is very sensitive to noise. It considers only pixel intensity and does not consider their location or neighborhood properties. As a result noisy images affect the effectiveness of this algorithm.

4. THE PROPOSED METHOD

In this paper, a new clustering based segmentation technique is proposed. This method can be applied directly on the noisy images. The proposed method reduces the effect of noise on the segmentation. The main advantage of this method is that no separate correction algorithm has to be applied before applying the segmentation algorithm. The proposed method has the following steps

1) Impulse Noise Detection
2) Segmentation

4.1. Impulse Noise Detection

For detecting the noise pixels, histogram of the noisy image is used. Images corrupted with salt-and-pepper noise will have two peaks at the maximum and minimum intensities in their histogram. An 8-bit gray scale digital image will have intensities in the interval [0,255].When the histogram of such an image is evaluated it is found that the histogram have two peak at the high end and low end intensities ie,at 0 and 255 [4]-[6]

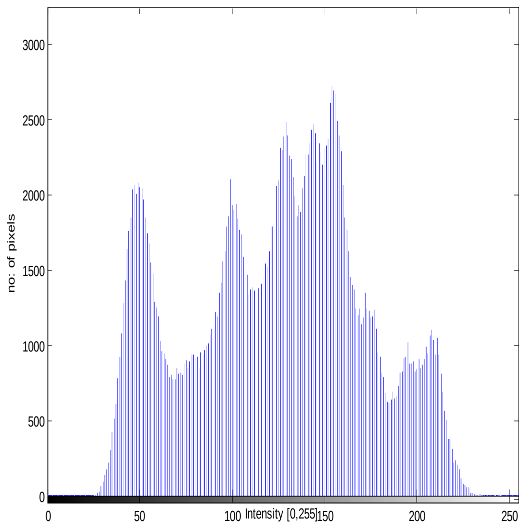

Fig.1. Histogram of the noise free Lena Image

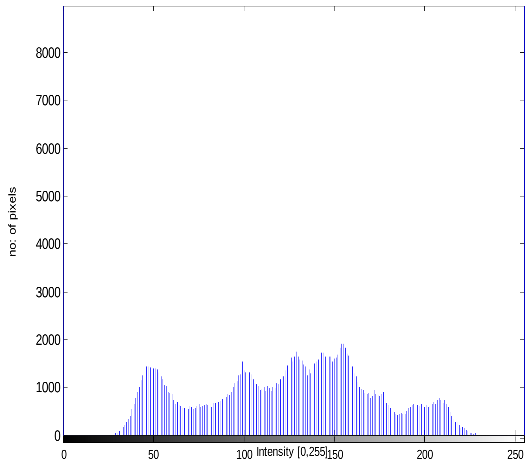

Fig.2.Histogram of Lena corrupted with 30% salt-and-pepper noise density

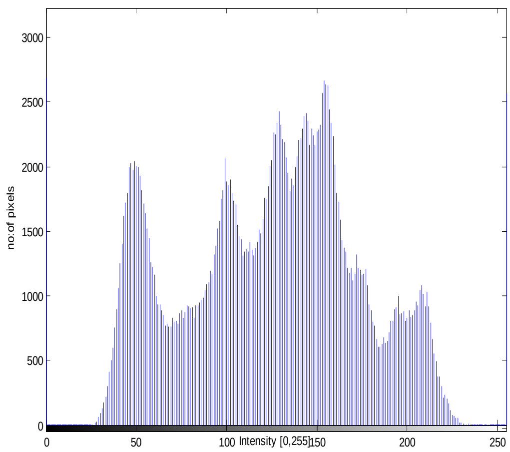

Fig.3. Histogram of Lena corrupted with 2% salt-and-pepper noise density

From the fig.2 it can be seen that for the image corrupted with 20% salt-and-pepper noise, there are two peaks at both the ends of the histogram .Under this condition, the assumption that salt-and-pepper noise intensities are the peaks of the noisy image histogram is true. But for an image corrupted with 2% salt-and-pepper noise density, it is observed that the positive noise peak is lower than the intensity of group of pixels in the image which is noiseless. In this case, if it is assumed that the intensities of the salt-and-pepper noise is the intensity of the peaks in the noisy image histogram, it is likely that the noisy pixels in the image would be left unchanged. To overcome this problem the detection begins by searching for the two peaks in the histogram from the two ends. Traversing the noisy image histogram from the left-side end towards the centre of the histogram, the search is stopped once the local maximum is found. The procedure is repeated for the right-side also usually for an 8-bit gray level image, the intensity values for the salt and pepper is taken as 0 and 255 respectively. These intensities will be used for finding the noise pixels in the image.

A binary noise mask will be created for identifying the location of the noise pixels. The binary noise mask $N(i.j)$ can be represented as

$$N(i.j) = \begin{cases} 0, \; X(i,j) = L_{salt} \; or \; L_{pepper} \\ 1, \; otherwise \end{cases} \quad \ldots\ldots\ldots (6)$$

Where , $X(i,j)$ is the intensity value of the pixel at the location (i,j).
In the binary noise mask, the pixels which are corrupted with salt-and-pepper noise will be set to 0 and noise free pixels are set to 1. The noise free pixels will be retained as such during the further clustering process. Those pixels which are identified as noise pixels will be replaced by a correction term.

4.2. Segmentation

The correction term can be found by using the equation

$$X'(i,j) = [1 - F(i,j)]X(i,j) + F(i,j)M(i,j) \quad \ldots\ldots (7)$$

Where $M(i,j)$ is the median, $F(i,j)$ is the fuzzy membership function.
For obtaining that correction term first we have to find the median of noisy pixels using a 3 x 3 window. The median value is obtained from the equation

$$M(i,j) = median\{X(i+k, j+l)\}, \text{where } k,l \in \{-1,0,1\} \ldots\ldots\ldots (8)$$

After calculating the median pixel value local information in the 3 x 3 window is found. This can be obtained by first calculating the absolute luminance difference and then the maximum absolute luminance difference. The absolute luminance difference can be obtained from the equation

$$d(i+k, j+l) = |X(i+k, j+l) - X(i,j)|, \quad \text{with } (i+k, j+l) \neq (i,j) \quad \ldots\ldots\ldots\ldots (9)$$

The absolute maximum luminance difference is calculated using the equation,

$$D(i,j) = \max\{d(i+k, j+l)\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

If minimum absolute difference is used, the minimum operator cannot distinguish between noise free pixels and noisy pixels. So we are using maximum operator here.

To this extracted local information fuzzy reasoning is applied so as to get fuzzy membership function $F(i,j)$. $F(i,j)$ can be obtained from the equation

$$F(i,j) = \begin{cases} 0, & D(i,j) < T_1 \\ D(i,j)^{\frac{T_1}{T_2 - T_1}}, & T_1 \le D(i,j) < T_2 \\ 1, & D(i,j) \ge T_2 \end{cases} \quad \text{-------- (11)}$$

Then the parameters obtained from the equations (8)-(11) are substituted in the equation (7) to obtain the correction term.

Then this correction term is used for replacing the noisy pixel during the process of grouping the data. This is done by replacing v_t in equation

$$v_t = \begin{cases} X(i,j), \; if \;\; N(i,j) = 1 \\ X'(i,j), \; if \;\; N(i,j) = 0 \end{cases} \ldots\ldots\ldots\ldots\ldots\ldots (12)$$

Then the segmentation is done using K-means clustering algorithm or FCM algorithm. For segmenting the image using KM clustering algorithm the value of v_t is substituted in equation (2) for finding the cluster centroids. All the noise pixels in the corrupted image will be replaced thereby reducing the effect of noise on further segmentation. Similarly, for segmenting the image using FCM clustering algorithm, v_t is substituted in the equation (4) to find the new cluster centroids.

5. PERFORMANCE ANALYSIS

A large number of segmentation methods are available today. In this paper, we are mainly dealing with clustering based segmentation techniques. These clustering based segmentation techniques include those which uses fuzzy concept also which is expected to give better results. Performance analysis of segmented images can be done both qualitatively and quantitatively.

5.1. Qualitative Analysis

In this method of analysis, segmented images are evaluated visually. But this method of analysis is subjective or depends on type of application. The result of qualitative analysis will be different for different evaluators. This is because each evaluator will have distinct standard for measuring the quality of segmentation.

In this paper, an image is applied with different levels of noise densities and then the proposed algorithm is applied to evaluate the different segmentation methods qualitatively.

5.2Quantitative Analysis

There are many techniques for quantitatively evaluating segmented images. These techniques can be classified into 3 different categories. They are analytic methods, supervised evaluation methods and unsupervised evaluation methods. In analytic method segmentation algorithms are treated directly based on some measures like complexity. In supervised segmentation method, the result of segmentation is compared with standard reference image which is segmented manually. In unsupervised segmentation method, the segmentation results are evaluated by judging the quality of segmented image directly to some predefined criteria.

In this paper, function F (I) is used for evaluation of segmentation. This function will give result which corresponds closely to visual judgment. The smaller the values of this function better the segmentation.

The objective quantitative evaluation function F proposed by Liu and Yang [7]

$$F(I) = \frac{\sqrt{R}\sum_{i=1}^{R} e_i^2}{\sqrt{A_i}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(14)$$

6. RESULTS AND DISCUSSION

In this paper proposed algorithm is applied on standard barn image and house image.

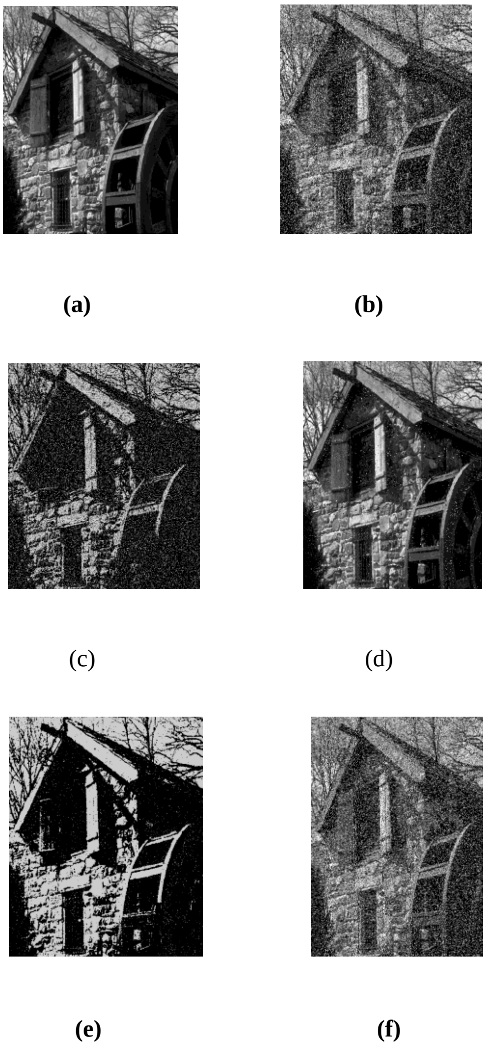

Fig.4. Image of barn (a) original image (b)noisy image with 30% noise density (c)FCM (d)image obtained after applying correction term (e)Proposed FCM method (f)KM (g)Proposed KM

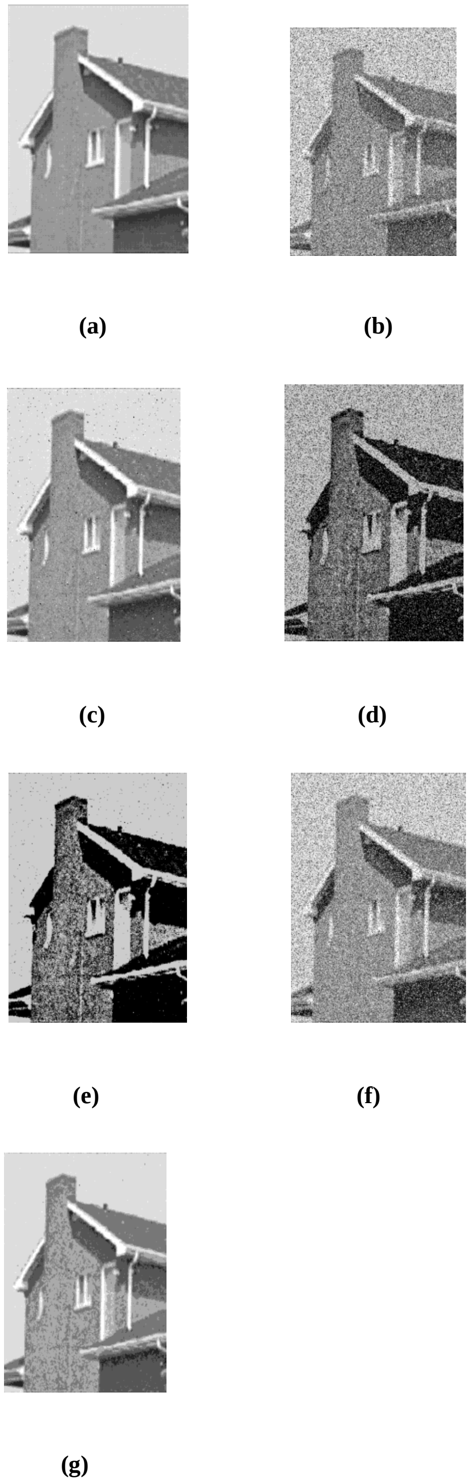

Fig.5. Image of House (a) original image (b)noisy image with 30% noise density (c)FCM (d)image obtained after applying correction term (e)Proposed FCM method (f)KM (g)Proposed KM

Consider the standard barn image of size 512 x 512 in the fig.2.a. When the image corrupted with 30% salt-and pepper noise density is segmented using both conventional and proposed methods, it can be seen that the proposed method give much better segmented image than the conventional method. In the conventional method the presence of salt-and-pepper noise will affect the segmentation whereas in the proposed method, the effect of noise on segmentation is greatly reduced. Similar is the case with the standard house image. So from the qualitative analysis it is clear that the proposed method outperforms the conventional FCM and KM clustering methods.

For the quantitative analysis of the segmentation, an evaluation function F (I) is calculated. In the case of standard barn image, F(I) of KM and proposed KM are 6.492 x e^12 and 3.6832 x e^12.The smaller the value of F(I) better the segmentation. Therefore from the quantitative analysis it is clear that proposed method gives better segmentation result. Also the F(I) of FCM and proposed FCM are 2.2138 x e^12 and 1.4242 x e^12 respectively. This indicates that proposed FCM method gives better segmentation result.

In the case of standard house image, F (I) of KM and proposed KM are 6.8364 x e^12 and 1.7106 x e^12.This indicates that proposed KM is better than the conventional KM. The value of evaluation function F (I) for FCM and proposed FCM are 2.3099 x e^12 and 1.2813 x e^12 respectively which indicates that the proposed method is better.

7. CONCLUSION

The proposed clustering based segmentation technique and the conventional clustering techniques are applied on standard test images corrupted with salt-and-pepper noise. Qualitative analysis it is clear that the proposed method outperforms the conventional FCM and KM clustering methods. Both the qualitative analysis and quantitative analysis indicates that the proposed method gives better segmented image than the conventional clustering techniques. This method can be tested on other segmentation method and algorithms. Anyhow this method is the better in time saving and reducing unnecessary techniques on image segmentation process.

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