A NEW IMAGE CLUSTERING AND COMPRESSION METHOD BASED ON FUZZY LOGIC AND DISCRETE COSINE TRANSFORM

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ABSTRACT

This paper presents a new approach to image compression based on fuzzy clustering. This new approach includes pre-filtering, fuzzy logic image enhancing and obtaining of cluster centers by performing the zig-zag method in discrete cosine transform coefficients. After applying the new method on sample images at different number of clusters, Better compression ratio, performing time and good validity measure was observed.

I. INTRODUCTION

Nowadays, importance of image compression increases with advancing communication technology. Limited hardware and budget is also important in sending of data fast. The amount of data associated with visual information is so large that its storage requires enormous storage capacity. The storage and transmisson of such data require large capacity and bandwidth, which could be very expensive. Image data compression techniques are concerned with reduction of the number of bits required to store or transmit images without any appreciable loss of information. Image transmission applications are in broadcast television; remote sensing via satellite, aircraft, radar, or sonar; teleconferencing; computer communications; and facsimile transmission. Image storage is required most commonly for educational and business documents, medical images. Because of their wide range of applications, data compression is of great importance in digital image processing [1,2,3].

In image segmentation coding techniques, image is segmented to different regions separated with contours, and coded with different coding techniques. Region growing, c-means, and split and merge methods are used generally for image segmentation. Beside of this crisp classical segmentation methods, the fuzzy logic segmentation methods were also seen very effective for coding [4,5,6,7].

In this study, A new image clustering and compression method based on fuzzy logic and discrete cosine transform was introduced for gray scale images together with pre-filter and image enhancing based on fuzzy logic. This method was applied to different sample images and high compression ratios and good validity measures were observed.

II. DISCRETE COSINE TRANSFORM

Discrete cosine transform (DCT) can be used at feature extraction, filtering, image compression and signal processing. There are alot of transforms different from DCT as Karhunen-Loeve transform (KLT), Discrete fourier transform (DFT), Hadamard transform and Slant transform. DCT has more efficient feature on energy compaction than DFT. DCT has also less complex calculation than KLT and DCT has good energy compaction feature as KLT [8,9]. Two dimensional DCT transform of f(x,y) is given by

$$\alpha(u) = \begin{cases} \sqrt{\frac{1}{N}} & \text{for } u = 0 \\ \sqrt{\frac{2}{N}} & \text{for } u = 1,2,\ldots,N-1 \end{cases} \quad (1)$$

$$C(u,v) = \alpha(u)\,\alpha(v) \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} f(x,y) \cos\left(\frac{(2x+1)u\pi}{2N}\right) \cos\left(\frac{(2y+1)v\pi}{2N}\right) \quad (2)$$

$x, y = 0, 1, 2, \ldots, N-1$
$u, v = 0, 1, 2, \ldots, N-1$

Where f(x,y) denotes a two dimensional sequence of NxN points and C(u,v) denotes NxN points DCT of f(x,y).

III. VALIDITY MEASURE

Cluster analysis has been playing an important role in solving many problems in pattern recognition and image processing. Many clustering algorithms have been developed and fuzzy clustering methods have been played more important role, because of its flexible structure [10,11,12]. Clustering quality is also important together with increasing of importance of clustering. So validity criterion was created, and based on a validity function which identifies overall compact and separated clustering. Several validity functions such as partition coefficient (PC), classification entropy (CE), partition exponent (PE), csc index (S) and so on, have been used for measuring validity mathematically [13,14,15,16]. PC and CE have slightly larger domains than PE, and in this sense are more general. But PC, CE and PE validity measures lack of direct connectionto geometrical property. S validity function also includes geometrical features [17,18]. S validity function is proportion of compactness to separation. S validity function is given by

$$S = \frac{\sum_{i=1}^{c} \sum_{j=1}^{N} \mu_{ij}^{2} \| v_i - x_j \|^2}{N \min_{i,t} \| v_i - v_t \|^2} \qquad (3)$$

Where μ_{ij} (i=1,2, ...,c , j=1,2,...,N) is membership value, it denotes fuzzy membership of data point j belonging to class i, v_i (i=1, 2, ..., c) is cluster center of each cluster and x_j (j=1,2,..., N) is pixel values of image. Validity function S is defined as the ratio of compactness to separation, and partition index is obtained by summing up this ratio over the all clusters. Smaller S gives more compact and separate clustering.

IV. NEW IMAGE CLUSTERING AND COMPRESSION ALGORITHM

Our algorithm operates in four steps.

- Pre-filtering, image enhancement based on fuzzy logic, smoothing and creation of crisp image.
- Separation of image to 4x4 blocks and transformation of each block by using discrete cosine transform.
- Selection of peak values of membership functions from transformed 4x4 blocks by zig-zag method.
- Obtaining membership values and cluster centers. Then creation of segmented image and compression by run- length coding.

As a result of imperfect sampling processes, real images usually contain high frequency and low amplitude noise that is nearly invisible to humans. Human visual system remove this noise by nonlinear smoothing charteristics of the lens and retina. Pre-filter was applied to reduce undesirable noise effects on our segmentation results [19]. Characteristics of pre-filter are similar to lens and retina. Smoothing pre- filter is given by

$$x^2(i) = x^1(i) + \frac{d_{-2}(i) + 2d_{-1}(i) + 2d_{+1}(i) + d_{+2}(i)}{8} \qquad (4)$$

$$x^1(i) = x(i) + \frac{d_{-1}(i) + d_{+1}(i)}{4} \qquad (5)$$

$$d_m(i) = \begin{cases} x(i+m)-x(i) & |x(i+m)-x(i)| < L \\ L & \text{otherwise} \end{cases} \qquad (6)$$

Where x (i) is ith pixel value in image. L is the filter constant and chosen to be 15.

After pre-filtering, image can be considered as an array of fuzzy singletons, each with a value of membership denoting the degree of brightness level according to membership function in figure 1 [20,21]. Using notation of fuzzy sets, we can write image array as

$$X^{\sim} = \begin{bmatrix} \mu_{11}/x_{11} & \mu_{12}/x_{12} & \dots & \mu_{1n}/x_{1n} \\ \mu_{21}/x_{21} & \mu_{22}/x_{22} & \dots & \mu_{2n}/x_{2n} \\ . & . & \dots & . \\ \mu_{m1}/x_{m1} & \mu_{m2}/x_{m2} & \dots & \mu_{mn}/x_{mn} \end{bmatrix} \qquad (7)$$

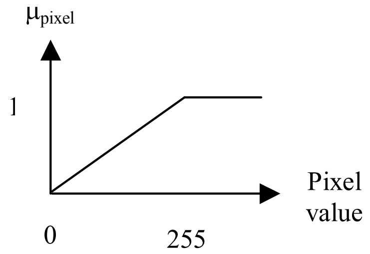

Figure 1. Membership function of pixels in image

The obtaining new membership values μ'_{mn} of pixels for enhancing is shown by

$$\mu'_{mn} = \begin{cases} 2(\mu_{mn})^2 & 0 \le \mu_{mn} \le 0.5 \\ 1 - 2(1-\mu_{mn})^2 & 0.5 < \mu_{mn} \le 1 \end{cases} \qquad (8)$$

Smoothing algorithm is used for reducing of noise by equation (9) and figure 2.

$$\mu_{00} = \frac{\mu_{-10} + \mu_{10} + \mu_{01} + \mu_{0-1}}{4} \qquad (9)$$

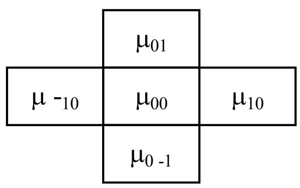

Figure 2. Pixels required around center pixel to use smoothing algorithm

After smoothing operation, image enhancement is applied again by using equation (8) and membership values are normalized between 0 and 255 to obtain crisp image.

At the second step of the algorithm, image is separated to 4x4 blocks and two dimensional discrete cosine transform is applied to each block. After obtaining DCT coefficients (D_i , i=1,2,...,16), Coefficients are normalized by equation (10) for assigning new values between 0 and 255.

$$D_i^1(i) = \left(\frac{|\min_i(D_i)| + D_i}{\max_i(|\min_i(D_i)| + D_i)} \right) x\ 255 \qquad (10)$$

At the third step of the algorithm, DCT coefficients are arranged in a row from low frequency to high frequency by zig-zag method (figure 3) [22,23]. Then these coefficients are compared with the coefficients in other blocks considering that they have same place in a block and the higher coefficients are chosen. Then they are put their own place in 4x4 block. Selection of peak values of membership functions is made by ordering of $D^1(1)$, $D^1(2)$, $D^1(3)$, ... , $D^1(16)$ coefficients according to number of cluster.

D(1)	D(2)	D(6)	D(7)
D(3)	D(5)	D(8)	D(13)
D(4)	D(9)	D(12)	D(14)
D(10)	D(11)	D(15)	D(16)

Figure 3. Zig-zag scan order

At the fourth step of the algorithm, membership values of original image pixels are found by cosine membership function.

$$S(x_0,x,y,z) = \begin{cases} 1/2+1/2\cos((x-x_0)\pi/(x_0-y)) & y \leq x \leq x_0 \\ 1/2+1/2\cos((x-x_0)\pi/(z-x_0)) & x_0 \leq x \leq z \end{cases} \qquad (11)$$

Where x_0 is the coordinate of the peak, x is the independent variable (image amplitudes) and y, z is the width of the band.

Cluster centers v_i are calculated by following formula presented in [5].

$$v_i = \frac{\sum_{j=1}^{N} \mu_{ij}^{m} x_j}{\sum_{j=1}^{N} \mu_{ij}^{m}} \quad ; 2 \leq i \leq c \qquad (12)$$

Where μ_{ij} (i=1,2, ...,c , j=1,2,...,N) is membership value, it denotes fuzzy membership of data point j belonging to class i, v_i (i=1, 2, ..., c) is cluster center of each cluster and x_j (j=1,2,..., N) is pixel values of image, m is fuzzification parameter.

After obtaining the membership values and the cluster centers, image is created and it is coded by run-length coding.

V. EXPERIMENTAL RESULTS

This new method (DCT-BIC) was applied to 128x128 dimensional five sample gray scale images and compared with results of fuzzy c-means (FCM) and hard c-means (HCM) algorithms. Comparing parameters are compression ratio, csc index (S) validity measure and number of iterations. Comparison results are given at table 1 according to different number of clusters (c). Original images and segmented images by DCT-BIC were also given in figure 4, 5, 6, 7, 8 corresponding to different number of clusters.

Our method provides better image compression than another methods according to experimental results. It preserves intelligibility of images together with this high compression ratio. The images obtained by DCT-BIC method has less smaller clusters, that generates noise effect, than images obtained by another methods. There isn't also any block effects in clustered images.

DCT-BIC method doesn't include mathematically iteration and it has less complex calculation than another methods. So it takes a little time to reach to the result. When examining clustering quality, Validity measures (S) of DCT-BIC are very similar to validity measures of another methods at the most of point and also it is better at some of points.

VI. CONCLUSION

Importance of image clustering and compression methods increases nowadays. A new image clustering and compression method (DCT-BIC) based on fuzzy logic and discrete cosine transform provides better compression ratio and performing time. This method can be used for pattern recognition additionally, Because it provides good validity measure. There isn't also selection of initial values at DCT-BIC method, so there isn't possibility to reach incorrect results. But some of methods as FCM and HCM has high possibility to go to a local minimum according to selection of initial values and may not give correct results. Because of these advantages, This new method is a good alternative method for image clustering and compression.

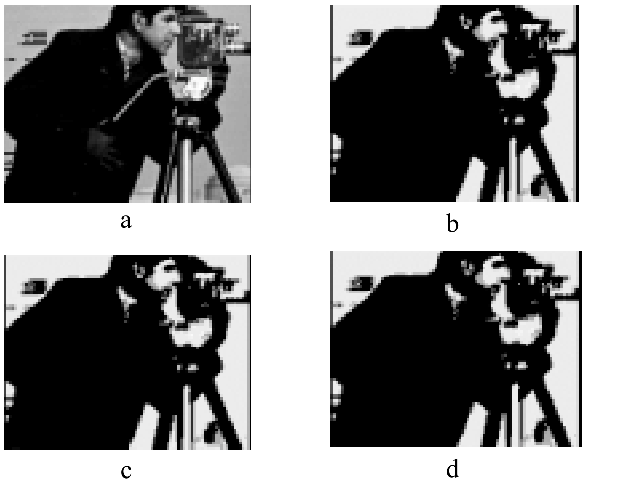

Figure 4. Cameraman image a) original image b) clustered image according to c=4 c) clustered image according to c=5 d) clustered image according to c=6

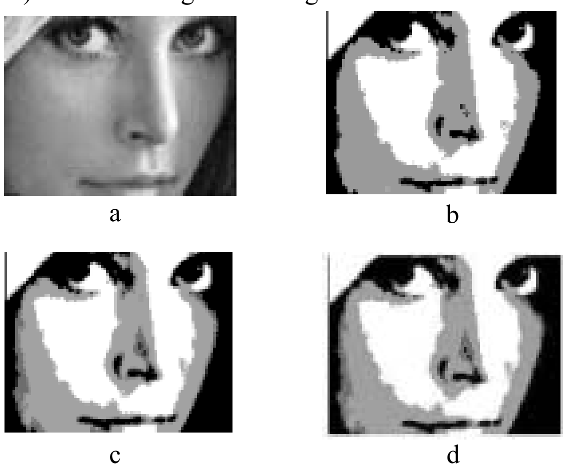

Figure 5. Lena image a) original image b) clustered image according to c=4 c) clustered image according to c=5 d) clustered image according to c=6

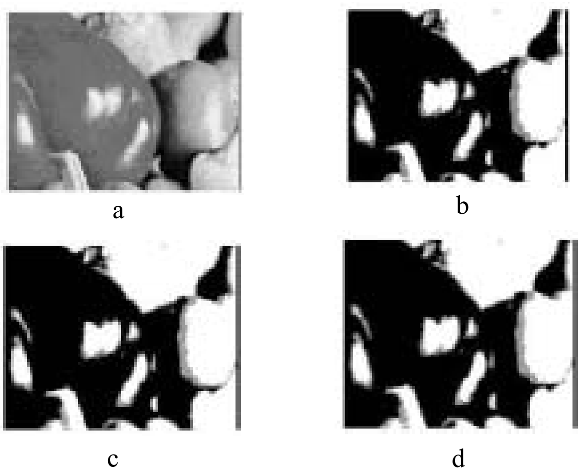

Figure 6. Pepper image a) original image b) clustered image according to c=4 c) clustered image according to c=5 d) clustered image according to c=6

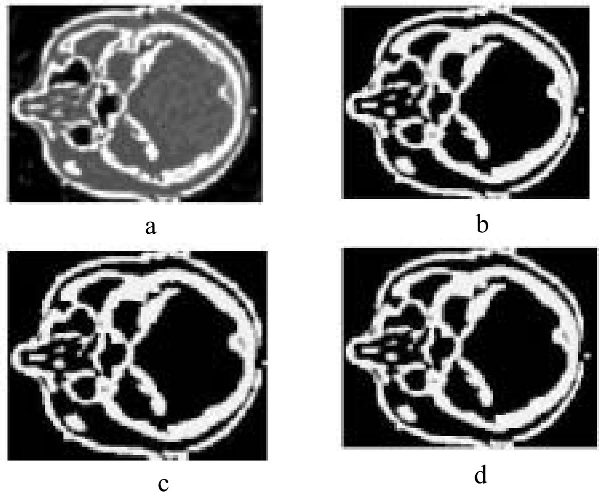

Figure 7. The image of computer aided brain tomography a) original image b) clustered image according to c=4 c) clustered image according to c=5 d) clustered image according to c=6

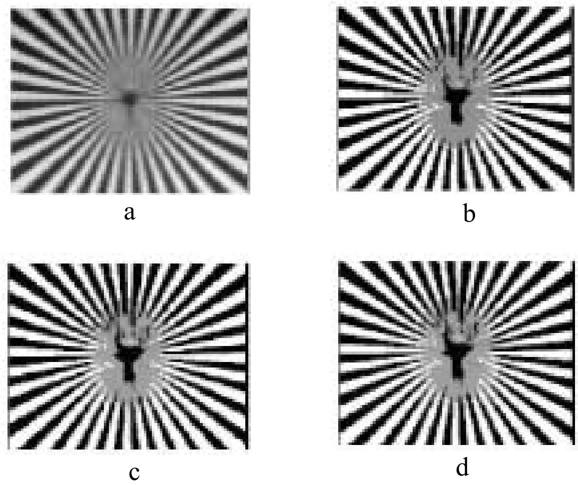

Figure 8. Test image a) original image b) clustered image according to c=4 c) clustered image according to c=5 d) clustered image according to c=6

Table 1. Experimental results.

	Cameraman			Lena			Pepper			Brain Tomog.			Test Image		
	DCT-BIC	FCM	HCM	DCT-BIC	FCM	HCM	DCT-BIC	FCM	HCM	DCT-BIC	FCM	HCM	DCT-BIC	FCM	HCM
c = 4															
Compression ratio	27.027	15.384	16.129	23.809	17.857	17.857	23.809	18.181	17.543	19.607	16.949	17.241	9.708	7.352	7.194
Validity measure	0.182	0.171	0.106	0.017	0.506	0.063	0.062	0.023	0.025	0.5092	0.014	0.014	0.099	0.032	0.037
Number of iteration	1	12	8	1	10	8	1	11	11	1	10	10	1	16	20
c = 5															
Compression ratio	25.641	13.157	15.873	19.120	14.925	14.705	21.052	14.492	13.888	18.215	14.084	14.492	8.865	6.134	6.172
Validity measure	0.183	0.158	0.059	0.069	0.058	0.085	0.041	0.052	0.063	0.0085	0.042	0.066	0.075	0.049	0.066
Number of iteration	1	26	28	1	15	8	1	5	5	1	21	10	1	9	14
c = 6															
Compression ratio	25.575	14.705	14.492	19.083	13.333	13.513	21.008	9.523	11.764	18.083	12.345	12.658	8.857	5.813	5.813
Validity measure	0.183	0.184	0.0894	0.069	0.087	0.074	0.042	0.145	0.074	0.5094	0.073	0.056	0.075	0.735	0.108
Number of iteration	1	26	14	1	28	7	1	16	8	1	20	9	1	23	17

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