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Analysis of Image Compression by Minimum Relative Entropy (MRE) and Restoration through Weighted Region Growing Techniques for Medical Images

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***Abstract*— In recent years, there is a spurt of publications on Information Theory based Image Compression Techniques. Specific regional characteristics of the images are associated with Information clusters. In this paper a novel approach of information theory based Minimum Relative Entropy (MRE) and Entropy methods for image compression are discussed. A two stage compression process is performed through homogenous MRE method, and heterogeneous MRE. The compressed images are reconstructed through Region growing techniques. The performance of image compression and restoration is analyzed by the estimation of parametric values such as Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR). Higher the PSNR better the reconstruction process. Six radiographic medical images of various sizes are analyzed and Maximum PSNR of 33 is achieved.**

***Index Terms*— Relative Entropy, Image Compression, Region Growing, Entropy.**

I. Introduction

Now-a-days, information theoretic approaches towards the image compression are popular among the research communities. There are two fundamental concepts being used. They are Shannon's Entropy and Relative Entropy (also known as Kullback-Leibler information distance, directed divergence, cross entropy).The first one aims to measure the information content of an image histogram and the latter enables us to describe the discrepancy between the image histograms of different images or in the same image [1]. The histograms show the distribution of information in the various regions of the image. These distributions form the Information clusters. Analysis of image through entropy clusters over a template is useful in segmentation. In this paper the image segmentation and description (compression) is performed by the Minimum Relative Entropy (MRE) method of Kullback-Leibler concept. In compression the fundamental idea is to reduce the redundancy and irrelevancy. Removing the duplication from the image is called as redundancy removal. Omitting the part of the signal that will not be noticed by the human visual system (HVS) is called irrelevancy reduction. There are three types of redundancies viz., spatial redundancy, spectral redundancy and temporal redundancy. In still image, compression is achieved by removing spatial and spectral redundancy [7].

A. *Need for Compression*

Image compression is a method to represent a digital image with reduced amount of data. In Literature a wide range of image compression methods such as Transformation of data, the projective representation on a smaller set of data, and Encoding of the data using encoders are studied and reviewed. Digital image compression aims at reducing the coding, inter pixel and psycho visual redundant information. The probability of occurrence of events (such as gray level values) can be used for the coding redundancy. For reducing the interpixel redundancy the 2D pixel array that is normally used for human viewing and interpretation must be transformed into a more efficient format. This transformation is called reversible if the original image elements can be reconstructed from the transformed image. The psycho visual redundancies can be reduced using the fact that the human eye does not respond with equal sensitivity to all visual information [7]. Therefore, without significantly impairing the quality of the image perception, certain information can be eliminated. Compressions of medical images are highly useful in telemedicine and telediagnosis of patients when there is transmission bandwidth constraint. The overall organization of the paper is as follows. After the introduction, we present the fundamental issues of the image compression in section II. Section III examines the methodology of Minimum Relative Entropy, Entropy Methods for compression and

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reconstruction by Region Growing. The results of the algorithm employed are discussed in section IV. Finally section V concludes the paper.

II. MATERIALS AND METHOD

The following block diagram of Fig 1. shows the process involved in the compression of a digital raw image. Raw images of two sizes 256X256 and 512X512 are analyzed. The probability of occurrence of each pixel is obtained by plotting the histogram of the image. Then the image is segmented as a co-occurrence region of 4X3 cell matrix, which is the size of the template. We have fixed the compression ratio at 12. Two types of segmentations are performed viz homogenous method and heterogeneous one. From the segmented image, the seed values are found per co-occurrence region.

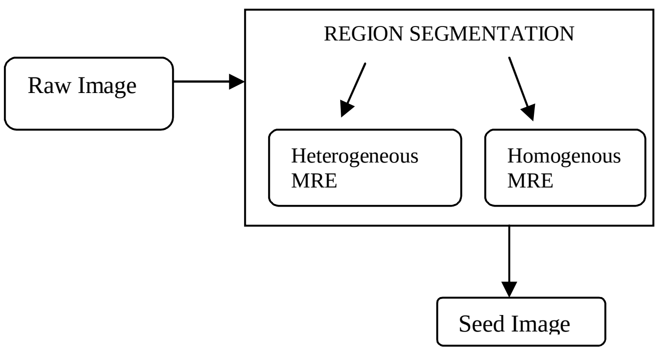


Fig. 1a. Block diagram for Entropy and MRE based image compression.

The reconstruction process is shown in the fig.1b.The region growing method is adopted for reconstruction of the image from its seed values. In this paper we discuss two types of region growing methods: 1.Ordinary filling, which is a simple expansion of seed value in the entire sub region of the template, and 2.Weighted filling, which is done by the filling of the region with seed values obtained through weighted pixel values of adjacent regions. The Peak Signal to Noise Ratio (PSNR) value of the reconstructed images is computed and compared. The image compression and reconstruction algorithms are discussed in the following section of the paper.

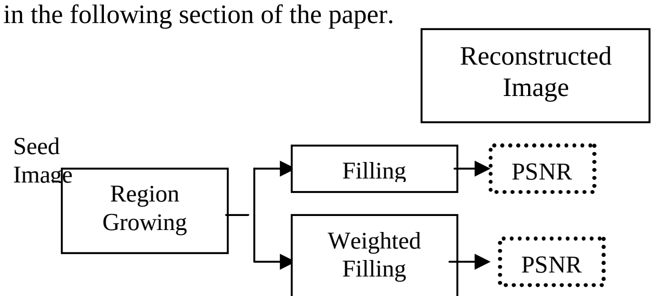


Fig. 1b. Reconstruction of the Original Image through Region Growing.

III. HOMOGENEOUS MRE AND HETEROGENEOUS ENTROPY METHODS FOR IMAGE COMPRESSION

This section gives details about the MRE compression, and employing both homogeneous and heterogeneous methods in detail followed by the technique of region growing. The main objective of this paper is to identify an efficient compression algorithm through entropy based clusters in the image. The following tasks are identified to accomplish efficient image compressions which are,

1. A bitmap image (raw image) of varying sizes 256X256 and 512X512 are taken.
2. The probability distribution of pixels in the sample image is computed through the histogram equalization technique.
3. The compression of image is obtained by computing MRE for the sample image through homogeneous and heterogeneous methods, and
4. The pseudo program for the MRE compression is also depicted.

A. Algorithm for MRE Compression

The generic representation of MRE optimization is explained, let p_m and q_n be probability measures for sources M and N, respectively. The relative entropy distance D (N||M) (also known as Kullback-Leibler distance) is defined as [3], [5]

$$D(N \parallel M) = \sum_{n} q_n(x) \log \frac{q_n(x)}{p_m(x)} \tag{1}$$

D (N||M) is a nonnegative continuous function and equals to zero iff p_m and q_n coincide. Thus D (N||M) can be naturally viewed as a distance between the measures p_m and q_n. However, D (.||.) is not a metric because it generally is neither symmetric, nor satisfies the triangle inequality. It is not difficult to see that we can have D (N||M) equal to zero while the conditional entropy rate H(N| M) is large and vice versa [2]. Thus, an information distance based on relative entropy can be used as an optimizer or cluster for image compression. To accomplish the image compression through MRE techniques the following procedures has to be incorporated,

1. The Bit map image is segmented by splitting the 256X256 image matrix into a number of 4X3 sub blocks, which is our template or co-occurrence matrix.
2. Then the 4X3 co-occurrence matrix is deduced into 4x1 matrix viz row wise optimization through MRE techniques.
3. Further the 4x1 co-occurrence matrix is reduced into one seed value through column wise optimization using MRE in the similar manner. The above mentioned tasks are carried out in phased manner of two stages such as row wise optimization and column wise optimization which are explained below.

B. Homogeneous Method

In this method both stage 1 and stage 2 employs Minimum Relative Entropy (MRE). The two stages in image compression are explained below,

Stage 1- Row wise Optimization.

The row wise optimization identifies the maximum possible influence of a particular pixel among the other two pixels in the template. The following stepwise procedures are adopted at stage 1 level.

1. 4x3 co-occurrence matrix W (i,j) , corner elements are padded with the same elements to avoid $\log (a_i/a_i) = 0$ where a_i is the probability of ith element.
2. Relative Entropy of $P_{i,1}(i,j)$ i^{th} element in the first row of W(i,j) matrix is found out through four neighbourhoods.

Considering $P_{i,1}(i,j)$ as source and P(i-1,j),P(i+1,j),P(i,j+1),and P(i,j-1) as destination elements through equation(1)

$$P_{i,1}(i,j)= P(i-1,j)+P(i+1,j)+P(i,j+1)+P(i,j-1) \quad (2)$$

Where Relative Entropy P (i-1,j)=$a_{i-1}\ln(a_{i-1}/a_i)$.

3. Likewise the Relative Entropy for other two elements in the row are calculated $P_{i,2}(i,j+1)$,and $P_{i,3}(i,j-1)$,
4. Find the minimum of row wise relative entropy as min ($P_{i,1}(i,j)$, $P_{i,2}(i,j+1)$, $P_{i,3}(i,j-1)$).
5. Now the row of three elements is converted into single element and replace the value of min (P (i,j)) with original probability values. This is repeated for all the 4 rows and now the matrix is reduced into 4x1 matrix.

Stage 2 - Column wise Optimization.

Column wise optimization identifies the relative ness among the four pixels in the 4x1 matrix. This is accomplished by

Using adjacent neighbourhoods of the (i,1) element in 4x1 row optimized template matrix and the same is shown below.

1. We find relative entropy of i^{th} P(i)=P(i+1)+P(i-1), where P(i) as the source element and P(i+1),and P(i-1) as destination through equation(1). Subsequently other relative entropies P(i+1)=P(i)+P(i+2) , and P(i-1)=P(i)+P(i-2) are found out.
2. Find the min {P(i),P(i+1), P(i-1)}for the i^{th} member in that particular group.
3. This procedure is repeated until a single optimum value is arrived. This single value represents the seed value of 4x3 co-occurrence matrix.

C. Heterogeneous Method

In this method, stage 1 Row wise optimization uses the traditional entropy method, which is defined as [6]

$$E = -\sum_{i=1}^{n} p_i \log p_i \quad (3)$$

The following step wise procedure adopted in this method is explained below,

1. Entropy of all pixels in the template 4x3 matrix is calculated through equation (3).
2. The average Entropy of a particular i^{th} row of three elements as $E_{i,avg}=1/3 \times (E_{i,1} + E_{i,2} + E_{i,3})$
3. Find minimum of min $(E_{i,avg}-E_{i,j})^2$ where j=1,2, and 3. Select the pixel which has minimum square difference between its entropy and average entropy in that particular row. This would reduce the 4x3 matrix into 4x1 matrix.

Stage 2. The column wise optimization is the same method which is used for homogeneous MRE is adopted. Pseudo Coding for the Homogenous MRE method is depicted below:

```
Begin
    Let I be the input image
    I'=segmentation (I);
    For i =1: No. of segments
        B'(x, y, i) =padding (B(x, y, i));
        Seed (i) =HOMOMRE (B'(x, y, i));
    End
End
```

Fig. 2. **Pseudo code for Compression**

D. Reconstruction of the Original Image from the Seed Image through Region Growing

Region growing is a procedure that groups pixels or sub regions into larger regions based on predefined criteria. The basic approach is to start with a set of seed points and from these grow regions by appending to each seed those neighbouring pixels that have properties similar to the seed (such as specific ranges of grey level).Region growing approach is the opposite of the split and merge approach. An initial set of small areas are iteratively merged according to similarity constraints. Fig 3 depicts the region growing process of reconstruction of the image. Start from the ***seed pixel*** obtained from the segmented image Region is ***grown*** by filling the neighboring pixels in two methods. In the ordinary filling method1 the entire is sub block length (4X3) is expanded with the seed pixel value. This is repeated over the other templates and a new image is reconstructed and its PSNR value is calculated.

Image Name	**Homogeneous MRE Technique (PSNR in dB)**		**Heterogeneous MRE Technique (PSNR in dB)**	
	Method 1	**Method 2**	**Method 1**	**Method 2**
Xray0	22.15	22.96	21.44	22.28
Xray1	22.67	22.91	24.38	25.25
Xray2	24.15	24.82	24.01	24.94

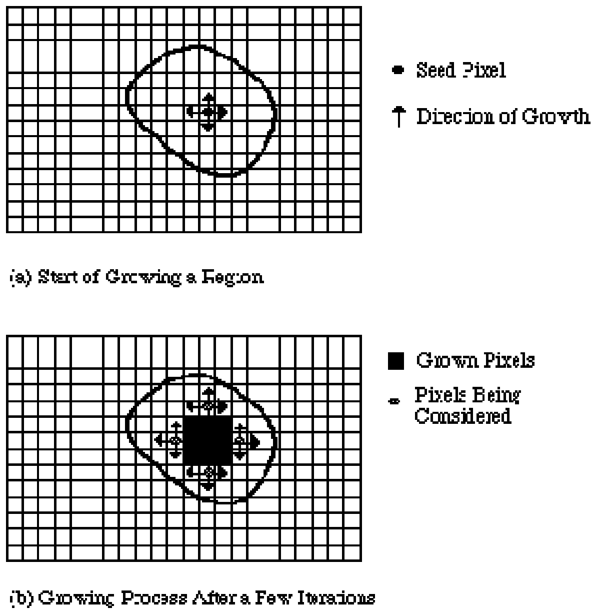


Fig. 3. Process of Region Growing.

The weighted filling method 2 is a two step process. In step 1core area of the sub region is filled by the seed values, and in step 2 the adjacent regions between the templates are filled with the weighted value of the seeds This method gives a PSNR value which is quite higher than the previous one obtained in method 1. This method provides gradual variation of contrast among the regions which is known as image enhancement. The simulation of these algorithms is performed using Image Processing toolbox of Matlab 6.1[4] and the results are discussed in the following section of the paper.

IV. RESULTS AND DISCUSSION

To identify better algorithms for image compression and reconstruction a comparative study is done based on their descriptor metrics. Two objective measures such as, MSE and PSNR are used for analysing the descriptors.

A. Fitness Evaluation

In image compression, the ideal measure of fitness would be the performance in an actual transform coder. PSNR is used as a fitness measure. PSNR is computed as [5]

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\|I(i,j) - K(i,j)\|^2 \tag{4}$$

$$PSNR = 10.\log_{10}\left(\frac{MAX_I^2}{MSE}\right) = 20.\log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \tag{5}$$

Here, MAX_I is the maximum pixel value of the image. When the pixels are represented using 8 bits per sample, this is 255. The obtained results for various sizes of sample images are tabulated in tableI and tableII.

Table .I Comparison of PSNR for image of Size 256X256

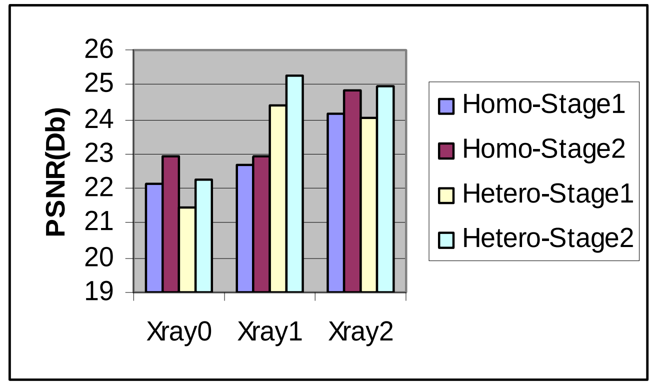


Fig. 4. Comparison of PSNR of the two stages of different compression techniques applied to image of size 256X256.

Table I and Fig.4 , shows the PSNR values for the images of size (256X256). It is observed that Homogeneous MRE technique PSNR values are placed at higher values for the images xray0and1. While the PSNR of the image xray2 through Heterogeneous MRE method is settled at higher value than its counterpart. In average 2.4% improvement which accounts 0.57 dB improvements in PSNR value is achieved between method 1 and method 2 reconstructions of Homogeneous MRE Compressed images. In the case of heterogeneous MRE compressed images the achieved PSNR improvement among the method 1 and method 2 reconstruction processes is about 3.6% and 0.88 dB.

The following Table II and Fig. 5 presents the comparison of the PSNR values for the two methods in the Homogeneous MRE and Heterogeneous MRE compressed images of size 512X512. Homogeneous MRE compressed images are reconstructed with higher PSNR values than their contemporaries. During the reconstruction process both compression methodology show same level of 2.5% average improvement in the PSNR values among the methods 1 and 2. This indicates that Homogenous method outperforms Heterogeneous method for the images X-ray 0,2,3,4 and 5 with the higher value of PSNR. Heterogeneous is settled at higher PSNR for the image X-ray1.

Table . II Comparison of PSNR for image of Size 512X512

Image Name	Homogeneous MRE Technique (PSNR in dB)		Heterogenous MRE Technique (PSNR in dB)	
	Method 1	Method 2	Method 1	Method 2
Xray3	28.02	28.75	27.65	28.65
Xray4	31.42	32.08	31.28	31.80
Xray5	32.44	33.45	32.21	33.01

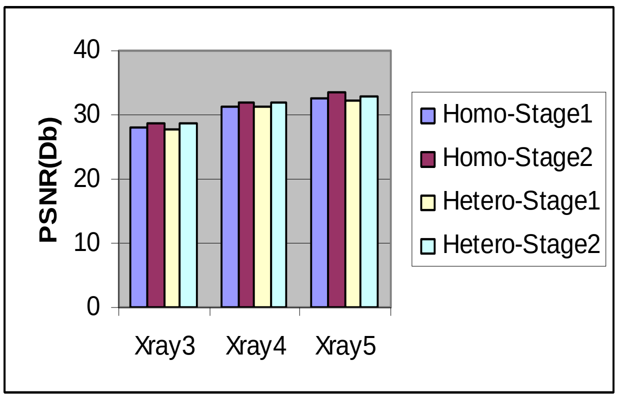
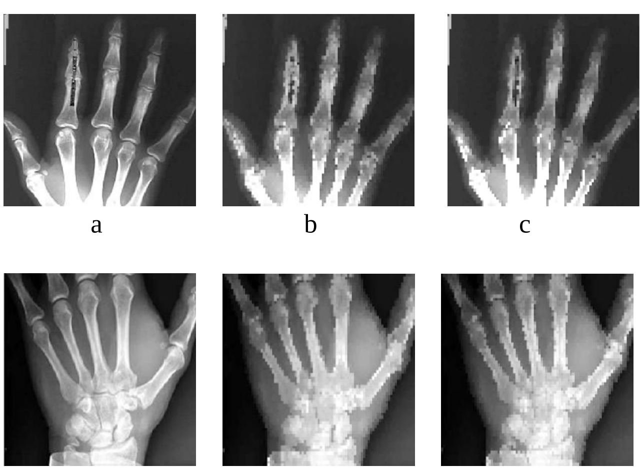


Fig.5. Comparison of PSNR of the two stages of different compression techniques applied to image of size 512X512.

B. Input Image and Reconstructed Images

The figure 6 and figure 7 depicts the six radiographic X-Ray images used for analyzing the MRE based image compression and region growing restoration algorithms.

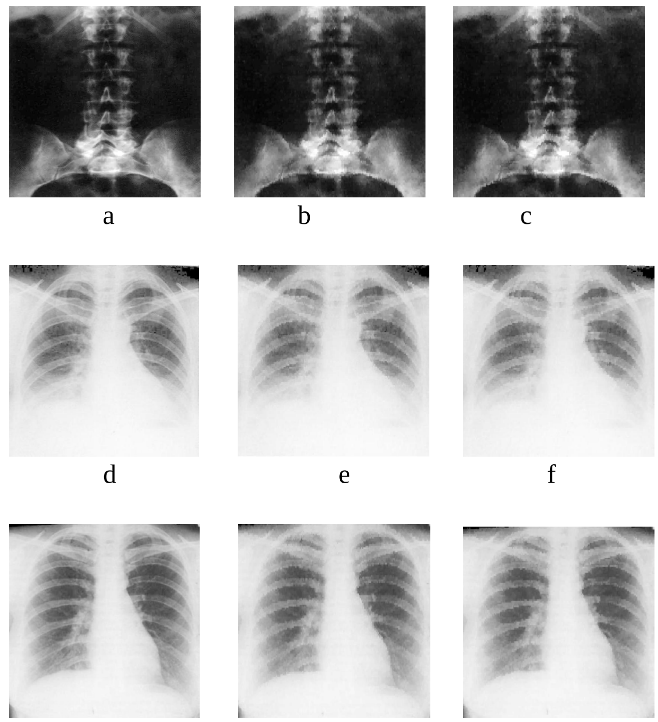


a b c

d e f

g h i

Fig. 6. a, d, g are the original X-ray 0, 1, 2 images of size 256X256. b, e, h Method 1 reconstructed images from homogeneous MRE compression. c, f, i Method 1 reconstructed images from heterogeneous MRE compression.



a b c

d e f

g h i

Fig. 7. a, d, g are the original X-ray 3, 4, 5 images of size 512X512. b, e, h Method 2 reconstructed images from homogeneous MRE compression. c, f, i Method 2 reconstructed images from heterogeneous MRE compression

V. CONCLUSION

The statistical methods and hypothesis testing are widely used for image compression. We have utilized the Minimum Relative Entropy and Entropy for Image Compression and Image Reconstruction is performed by Region Growing Methods. A standard compression ratio of 12 is obtained in our method. The PSNR of the reconstructed images shows that the utilized methodology is highly image specific in nature. Region growing reconstruction method is often plugged with low PSNR values. This is due to more number of edges in the radio graphic images. In future a combination of algorithms such as edge preservation one above said MRE methods will be studied to improve the PSNR values. Further research will be in the direction of generic image reconstruction through knowledge based techniques.

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