A Novel Criteria for Quad-Tree Partitioning of Images

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***Abstract*—This paper deals with partitioning of images for processing them for various applications. Adaptive block size image processing techniques are capable of enhanced performance than fixed block size processing systems. However, the criterion for adapting the block size still remains to be investigated. One among the most commonly used techniques for image segmentation is Quad-tree partitioning. This paper introduces a new method based on UMRT for optimized Quad-tree partitioning of images for various applications. The UMRT based criterion for Quad-tree partitioning is proposed to determine the block size suitable for a particular area of an image. The purpose of the algorithm is to take advantage of large uniform regions that can be processed as a single large unit instead of smaller units and fine details of the image can be processed as smaller units. It is shown that the UMRT based decision criterion offers better partitioning for all types of images tested.**

***Index Terms*—Quad-tree, MRT, UMRT**

I. INTRODUCTION

Segmentation is the process of partitioning an image into several non-overlapped regions such that each of these regions is homogeneous while the union of any two adjacent regions is not homogeneous. There are many segmentation techniques in the literature [1]-[4]. Segmentation techniques depend on the type of image which being segmented and the application in which this segmented image is to be used.

The ultimate aim for any image segmentation system is to decompose an image into different regions with homogeneous information. The level of decomposition is decided by the subjective quality measurement like the Human Visual System (HVS). The HVS recognizes an image through its regions, not through its pixel values. Efficient image segmentation is achieved when extracting this information [5], [6]. High quality decomposition of images is obtained when the image is segmented into regions having widely differing perceptual importance. Regions of each category are then to be processed using distinct procedures, suitable for preserving the main visual characteristics of each category.

For its simplicity and minimum overhead as well as efficiency, Quad-tree representation [7] has been exploited by many image processing techniques for partitioning images [8], [9], [l0]. Quad-tree is an efficient data structure that requires only a small overhead bit-rate by restricting the shapes and the number of possible sizes of the final regions to a predetermined set of options. Quad-tree is a top-down segmentation approach. It starts by subdividing initial size blocks into smaller quadrant blocks until a certain smoothness criterion is satisfied or a certain minimum block size is reached (leaf blocks). That is, square images are recursively decomposed into four square sub-images. Block variance-based criteria are usually used to measure the smoothness of the segmented blocks and to consequently classify them [8], [9]. Quad-trees have long been used in general image coding

A K-level Quad-tree structure is shown in figure. 1. A Quad-tree is said to be a K-level Quad-tree if the lowest level allowed is K-1. It can be represented by assigning 0 to non-leaf nodes and 1 to leaf nodes. Each node in a Quad-tree represents a sub-image. If the sub-image needs to be split into four quadrants, then the node will generate four children's nodes. Otherwise, the node becomes a leaf.

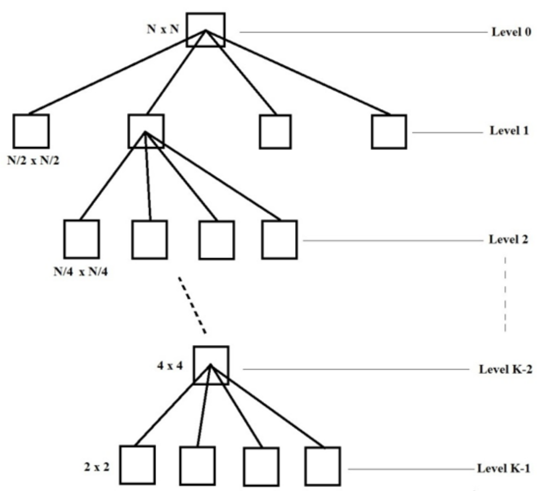

Fig.1. K level Quad-tree

Various measures are used to determine whether a sub-image should be segmented or not. Block variance is the most widely used measure for decision making. Although block variance may be considered as a local statistical measure with respect to the whole image, it is still a global statistical measure with respect to the sub-image itself. Block variance (the mean squared deviation from the block mean) does not consider the pixel value distribution within the sub-image. In this paper, a criterion based on Unique Mapped Real Transform (UMRT) [12] is proposed to determine whether a sub-image needs to be divided into smaller ones.

II. PROPOSED UMRT BASED CRITERION

The proposed method is UMRT [12] based approach. UMRT is a compact form of Mapped Real Transform (MRT). MRT and MRT based Image coding are explained in [11], [13] & [15]. For better understanding of this problem, MRT can be explained as follows.

Let the data matrix be $X_{n1,n2}$, $0 \le n_1, n_2 \le N-1$ and the MRT be

$Y^{(p)}_{k_1,k_2}$, $0 \le k_1, k_2 \le N-1$ and $0 \le p \le M-1$, $M=N/2$,

were

$$Y^{(p)}_{k_1,k_2} = \sum_{\forall (n_1,n_2)|z=p} X_{n_1,n_2} - \sum_{\forall (n_1,n_2)|z=p+M} X_{n_1,n_2}$$

$$z = ((n_1 k_1 + n_2 k_2))_N \qquad (1)$$

Equation (1) maps the NxN data matrix into M matrices of size N×N in the frequency domain using real additions only.

The inverse transform relation is as follows

$$X_{n_1,n_2} = \frac{1}{N^2} \sum_{q=0}^{1} X^{(q)}_{n_1,n_2}, \quad 0 \le n_1, n_2 \le N-1$$

where $$X^{(q)}_{n_1,n_2} = \sum_{\forall (k_1,k_2,p)|j=q} Y^{(p)}_{k_1,k_2} - \sum_{\forall (k_1,k_2,p)|j=q+M} Y^{(p)}_{k_1,k_2}$$

$$j = ((((-((n_1k_1 + n_2k_2))_N))_N + p))_N$$

2.1 Unique MRT (UMRT)

MRT [11] is an evolving transform that helps in frequency domain analysis of 2- dimensional signals without any complex operations but in terms of real additions only. The MRT mapping is highly redundant. A compact unique MRT (UMRT)[12] representation is derived by eliminating the redundant elements present in the MRT representation [12].

The Equation (1) maps the N × N data matrix, $X_{n1,n2}$, into M matrices of size N × N in the frequency domain using real additions only. $Y^{(p)}_{k_1,k_2}$ is the MRT matrices, where $0 \le k_1,k_2 \le N-1$ and $0 \le p \le M-1$, $M=N/2$,. The MRT representation shows a specific pattern of redundant elements in the MRT matrices. For a two-dimensional signal of size N × N, the total number of MRT coefficients is $N^3 / 2$, however only N^2 coefficients are unique [12]. Thus, the MRT mapping is highly redundant. The UMRT representation is derived by eliminating the redundant elements present in the MRT representation. Different algorithms are proposed for identifying and placing the N^2 UMRT coefficients in an N × N matrix [13]-[15].

The magnitude of the UMRT coefficients except the DC coefficient is a measure of the homogeneity of the sub-image under consideration. If the magnitude of any of the UMRT coefficients, except the DC coefficient, of a particular N × N sub-image is higher than a threshold value t, then the sub-image under consideration contains edge or inhomogeneous area and therefore that should be partitioned in to four N/2 × N/2 sub-images. While computing each UMRT coefficient, a comparison is made between the computed UMRT coefficient and the threshold value t. Whenever a UMRT coefficient overcomes the threshold value, the UMRT computation stops and the sub-image is subject to further segmentation.

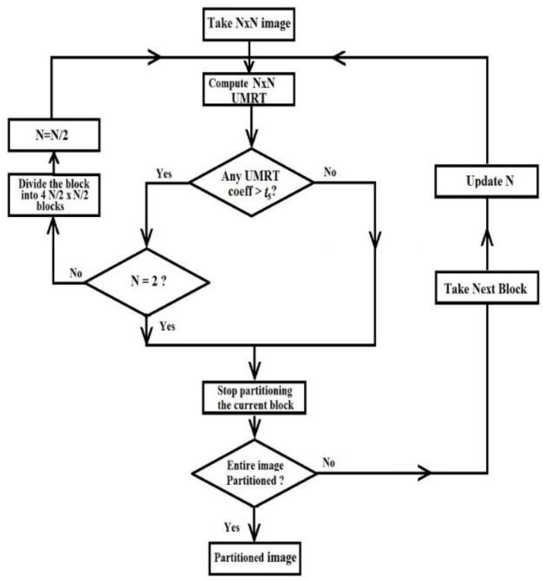

Fig.2. Proposed partitioning scheme

This process repeats until either the smallest sub-image size is reached or the UMRT coefficients are less than the threshold t. The proposed partitioning scheme is shown in figure. 2. Experiments proved that 100 is a good value for the threshold t. Figure. 3 is Quad-tree partitioned Lena image using the proposed UMRT based criterion.

III. RESULTS AND ANALYSIS

The efficiency of the proposed algorithm is analyzed by segmenting several images. As a representative result, the partitioning of the Lena image for different values of t is shown in figure. 4. The figure. 4(a) represents the partitioning when t = 100, (b) represents the partitioning when t = 150, (c) represents the partitioning when t = 200 and (d) represents the partitioning when t = 300. Likewise, by varying the value of t, the segmentation can be controlled depending on the application in which it is used. Experiments proved that 100 is a good value for t in transform coding-based image compression techniques. Table 1. Shows the results obtained when the proposed Quad-tree partitioning method with t = 100 is applied to UMRT based transform coding of images.

Table.1. Results obtained when the proposed scheme is applied in image coding

Image	bpp	PSNR (dB)
Lena	0.31	30.27
Baboon	0.85	24.84
Barbara	0.61	27.08
Peppers	0.32	30.49
Elaine	0.31	29.93
Cameraman	0.30	31.03

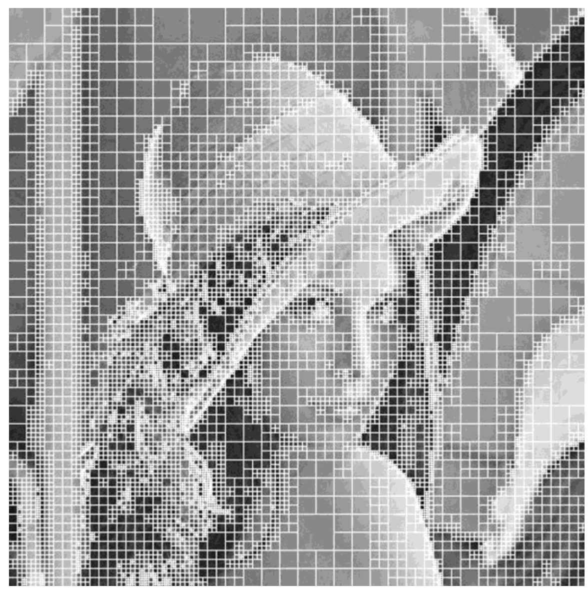

Fig.3. Segmented Lena Image

IV. CONCLUSIONS

In this paper, the image partitioning problem, using Quad-tree technique, for the sake of image processing is considered. A new UMRT measure is proposed. The proposed method is capable of partitioning images according to the statistics of the pixel values, which leads to a much better image segmentation, consequently to higher image compression ratios with lower image degradation.

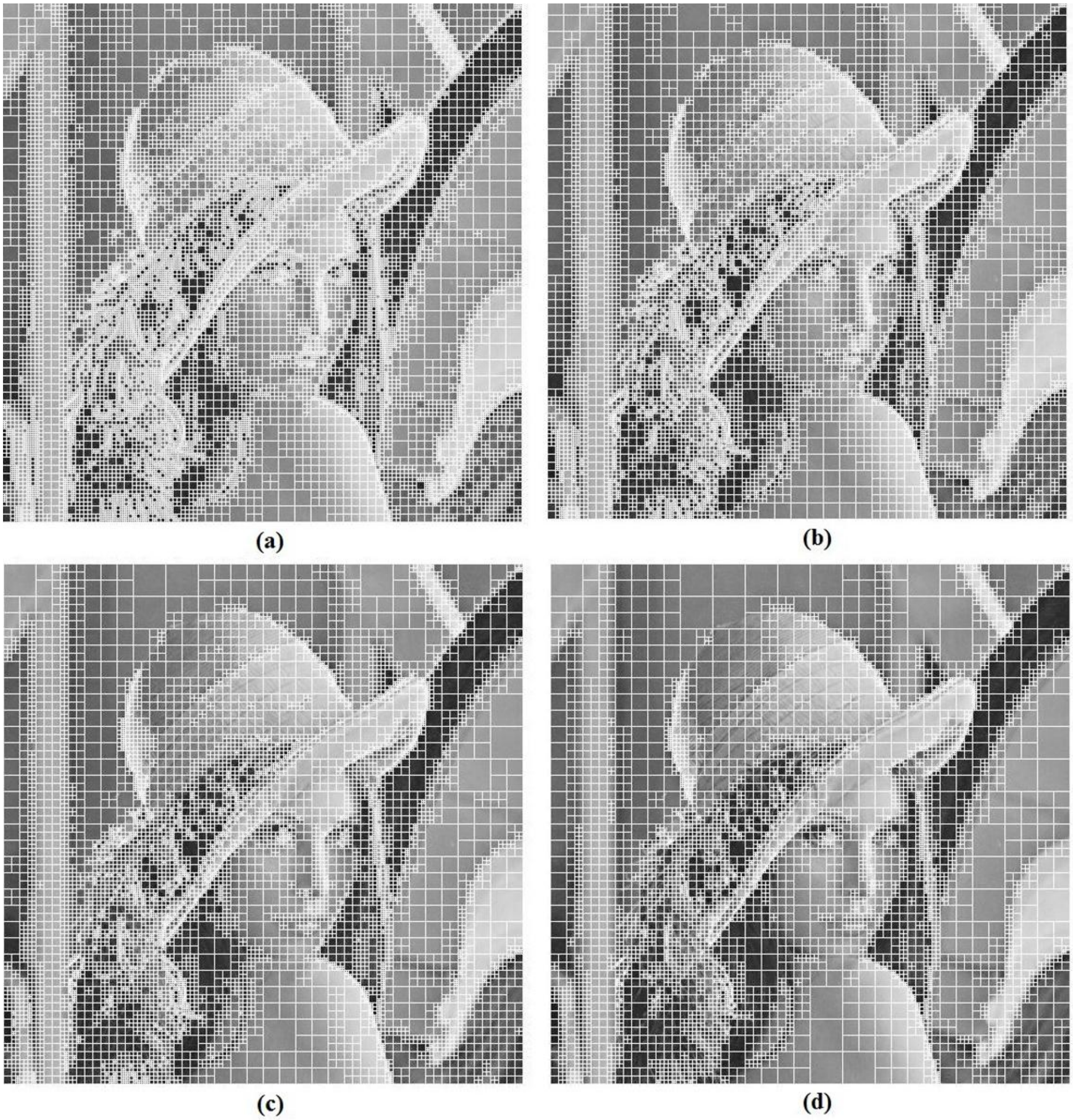

Fig.4. Partitioned Lena image for different values of t (a) t = 100 (b) t = 150 (c) t = 200 (d) t = 300.

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