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Development and Performance Evaluation of Efficient Low-complexity SPIHT Image Coder

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Abstract- Wavelet transform is one of the advanced, effective and computationally fast methods for image data as well as video compression. The wavelet based image compression is particularly a non-reversible method that has been growing computationally more complicated as they getting more accurate and reliable. In this work we have developed an image compression technique based on main concepts related to partial ordering of the coefficients of image matrix elements by magnitude with transmission of its order by a subset partitioning approach that is replicated at the decoder thereafter the ordered bit plane transmission of refined bits is performed and at last exploitation of the self-similarity of the image wavelet transform across different scales is applied. The partial ordering is obtained by the comparison of coefficient element magnitudes to a set of octavely decreasing thresholds. The bit pattern represents that an element is significant or insignificant for a particular selection of given threshold, depending on whether or not it is above of that threshold. This algorithm offer an excellent performance can be better understood. These concepts involves partial ordering by magnitude with a partitioning and sorting method such that the ordered bit plane transmission and exploitation of self-similarity in between different scales of image wavelet coefficients. The proposed image compression method present a different implementation, based on set partitioning in hierarchical trees (SPIHT), which provides even better performance than already reported extension of the wavelet based compressions that surpassed the performance of the conventional methods like DCT and run length like codlings . The image compression files results are calculated by original images for compression ratio and with reconstructed by the decompression methods for PSNR. The results are found either comparable to or surpass previous results obtained by other computationally complex methods. In addition of this the developed compression and decompression methods are very fast, and the performance can be made faster, with only small loss in performance, by reducing the bitrates values.

Keywords: SPIHT, NLS, DWT, data compression, image coder.

1. Introduction:

As we know that there is a need to limit the volume of the image data for image processing and for this purpose compression algorithm is required so that the image can be reconstructed from the compressed data volume. Image data consists of a lot of redundancies and compression can be achieved by removing these redundancies present in image data. In an image three types redundancies can be identified as follows. These are inter pixel or spatial redundancy, psycho-visual redundancy and coding redundancy. Inter pixel redundancy is related to the similarly among neighbouring pixels. In an image, neighbouring pixels are likely to be of the same intensity, and therefore can be predicted. The difference between the adjacent pixels can be used to represent an image. Psycho visual redundancy means that for human eye all the visual information is not sensitive. Viewing an image, the observer searchers only for distinguishing features like edges or textural regions and mentally combines them into a recognizable group. The elimination of psycho visual redundancy remove the quantitative information and known as quantization.

This provides lossy image compression. An image is said to have coding redundancy if the codes assigned to a set of events have not been selected to take the full advantage of the probabilities of the events. Data compression is achieved by assigning fewer bits to more probable events. The uncompressed image usually is coded with each pixel by a fixed length. For example, an image with 255 grey scales is represented by an array of 8-bit integers. Using variable length coding schemes image compression can be achieved.

Wavelet transform offers a multiresoluton signal representation, so it has the potential to support scalability. Over the past couple of decades, researchers have been working on wavelet based image coding to facilitate better image compression. A Wavelet based coder provides scalability. The embeddedness property of the bitstream provided by the embedded wavelet image coding algorithm guarantees the SNR scalability. Among the wavelet based coding schemes, embedded zerotree wavelet (EZW) [3] algorithm, developed by Shapiro is quite popular for its low complexity, full rate embeddedness and good compression efficiency. The EZW coder was further developed by Said and Pearlman in their work title by set partitioned in hierarchical trees (SPIHT) [4] and has better compression efficiency and has least complexity. SPIHT coder thus enjoys the benchmark status for embedded wavelet image coding. SPIHT coder uses three lists to store the index of the wavelet coefficients of the image and the entries in the list varies, depending upon the factors like, significant pixels, significant sets and bit-rates. So as the bit rate increases, entries in the list increases, memory requirement increases. Due to the use of these lists, extra memory is required to handle the lists thereby increasing the complexity of the coder increases. To reduce the memory requirement as well as complexity of the image coder, many researchers have been working to develop the listless version of the embedded zero tree coder [5-8].

This work is motivated by the distinct role of scalability and embeddedness in the wavelet based image coding algorithm application for transmission of images over heterogeneous network [9, 10] and the success of zero tree based coding approaches such as EZW and SPIHT. Presented work in this thesis proposes three listless versions of SPIHT coding algorithms. The main objectives of the research are listed below:

Efficient Compression: The proposed coders should be able to efficiently encode the visual information. Compression performance of the proposed coders should be comparable with the state of art coders. Providing scalability with listless implementation of the coder, the proposed coder should not result into serious loss of compression efficiency.

Memory Efficiency: Due to constraint in storage devices in mobile, computer, PDA, limitation of bandwidth of the channel and limitation in power backup, the proposed coders should use less memory to encode/ decode the image compare to the state of art coders.

2. Related Work:

Asad Islam and William A. Pearlman (1998), [1] they proposed an embedded stratified image coding algorithmic rule of low complexness. It exploits 2 elementary characteristics of a picture rework the well outlined hierarchical data structure, and energy cluster in frequency and in house. The image committal to writing algorithmic rule developed here, except being embedded and of low complexness, is incredibly economical and is akin to the simplest illustrious low-complexity image committal to writing schemes obtainable nowadays.

Zhitao Lu, et. al (2000), a wavelet ECG data codec based on the Set Partitioning In Hierarchical Trees (SPIHT) compression algorithm is proposed by **Zhitao Lu, et. al**. [2] The SPIHT algorithm has achieved notable success in still image coding. They modified the algorithm for the one-dimensional (1-D) case and applied it to compression of ECG data. The experiments on selected records from the MIT-BIH arrhythmia database revealed that the proposed codec is significantly more efficient in compression and in computation than previously proposed ECG compression schemes and the coder also attains exact bit rate control and generates a bit stream progressive in quality or rate.

Keun-hyeong Park and HyunWook Park, (2002), [10] according to them numerous image-coding applications like internet browsing, image databases, and telemedicine, it's helpful to reconstruct solely a district of interest (ROI) before the remainder of the image is reconstructed. during this work, associate ROI committal to writing practicality is incorporated with the set partitioning in stratified trees (SPIHT) algorithmic rule for wavelet-based image committal to writing. By putting a better stress on the remodel coefficients relating the ROI, the ROI is coded with higher fidelity than the remainder of the image in earlier stages of progressive committal to writing. the overall thrust of this analysis is to spot necessary coefficients in wavelet-transform domain for the decoder to reconstruct the required region. This new methodology provides higher performance than the antecedently bestowed ways.

Hala H. Zayed et. al., (2012), [11] according to them In three-dimensional show supported integral imaging (II) the compression of the basic pictures could be a major ought to be enforced in real time applications. during this work, they planned Associate in Nursing Integral Imaging (II) lossless compression software engineer supported three-dimensional set partitioning in stratified trees, 3D SPIHT. the basic pictures are stacked to create a 3 dimensional image. 3D moving ridge remodel is performed, then 3D SPIHT cryptography is applied. Simulations are performed to check the performance of the 3D compression system. The results show that the planned system has superior compression Performance compared to a pair of DSPIHT.

3. Methodology:

This is also a listless implementation of SPIHT algorithm with reduced markers, compared to NLS, MLS-I and MLS-II. It also works on wavelet transformed (using lifting approach) images and coefficients are stored in linear index [9]. The linear indexing allows the addressing of wavelet coefficients with single index instead of two indexes (for rows and columns). The linear indexing also simplifies tracking of sets partitioning. MELS uses the set structure and partitioning rules similar to that of SPIHT and NLS and produces same amount of total bits in each pass but with slightly different bit stream. This coder does not use any list or state marker for recording the state of pixel and in this coder markers are used to only record the state of set or subset of the trees. As we know that the SPIHT coder uses two lists to store the index of significant and insignificant coefficients respectively. This may be recalled that the previously proposed coders, the MLS-I and MLS-II used markers to record the state of pixel for coding the image, but for reducing the memory requirement and the complexity, while maintaining the PSNR scalability and other characteristic of the coder, the proposed MELS algorithm does not use any list or marker to record the state of significance /insignificance information of any pixel. While testing a coefficient against a threshold in the lowest sub-band (LL), there are three possibilities at each pixel. The coefficient may be insignificant or newly significant or it was significant in the previous passes, but now, needs only refinement bit in this present pass.

So, in each pass in the LL band, the proposed coder checkes these three possibilities at each pixel and codes the coefficient. Once the coefficient is found significant, its magnitude and sign information coded by one bit each respectively and in the subsequent passes, the coder generate only refinement bit for that pixel. The proposed algorithm

also uses the marker (SMT) as used by the previous two proposed algorithms to keep track of significant/insignificant sets or trees. SMT markers perform the function similar to that performed by LIS in SPIHT algorithm. Each node (having descendents) of trees is assigned
a suitable SMT value as follows.

SMT = '0' The node is not under consideration for significant test;
SMT = '1' Type A node, i.e. a node whose children and grand descendents are to be tested for significance;
SMT = '2' Type B node, i.e. a node whose only grand descendents are to be tested for significance;
SMT = '3' Type A and Type B sets of a node are significant, immediate offspring (four children of parent node) will be checked for significance, insignificance or refinement;

The first three SMT markers of all the proposed algorithms have the same function, but indication of the fourth marker in this algorithm is different from the MLS-I and MLS-II coders. Since, we are not using any marker to record the state of pixel, so, in the case when both Type A and Type B sets of a node would be significant, then the coder check the status of the immediate four children (pixels) of the parent node, where as the fourth marker of the MLS-I and MLS-II coders are used to indicate that there is no need to check the status of the node of sets or subsets of the present tree. As we have discussed earlier that the three-fourth of total coefficients lying in three lowest sub-bands of the wavelet pyramid and have no descendents (leaf nodes of trees). Therefore only one-fourth of nodes in trees should have assigned SMT value. So, during the significance test of zero tree, a node may have in any one of the four above defined possible states, and for these four states only 2 bits marker are required for each node of the tree in the given image. There is no need to assign 2 bits marker (SMT) for each pixel of the image. As a result, MELS coder is used only 0.5 bits/node memory to encode the image.
In the proposed coder, each tree node of LL sub-band is initialized with SMT = '1' and remaining tree nodes are set to SMT = '0'. During scanning of the trees to test for significance, if a Type A tree is found significant, it is partitioned into four children and a grand descendent set. First four immediate descendants (offsprings) are checked for their significance and their pixel states are coded by a sign and magnitude bit respectively. Then grand descendents are checked for their significance and if found significant, then the four new Type A with offspring as root node will be formed (assigned SMT = '1'), and original root node is reassigned SMT = '3', otherwise the tree node will be marked as Type B tree (SMT = '2'). It is possible that in next subsequent passes, the immediate offspring of a parent node of a significant Type A set may be insignificant, significant or need only refinement and the proposed algorithm does not use any list or marker to track for significance or insignificance of the pixel. So, before scanning the Type B (assigned SMT = '2') tree for significance, the proposed coder checks the status of four children of the parent node, these four offspring are checked sequentially for their significance, insignificance or refinement. Now, if Type B set is significant, then, four new nodes will be assigned Type A, and the original root node is reassigned SMT = '3', otherwise node will remain indicated by SMT = '2'. If we do not checked the status of four offspring of the parent node before significant test of Type B set, then the immediate four offspring of the parent node will remain unchecked in the consequent passes until Type B set become significant. Since, we have already used marker SMT = '3' at the parent node in the case Type A and Type B both significant. So, during searching the tree node in the subsequent passes, if node have SMT = '3', in this case the proposed algorithm checked the immediate four offspring of the parent node for significance/insignificance or refinement. The nodes are checked sequentially for their significance. The No list SPIHT(NLS) [5] coder uses four markers (MIP, MSP, MNP and MCP) to define the states of a pixel, two markers MD and MG to represent the Type A and Type B nodes respectively but in addition, it uses skip markers (MN2, MN3, MN4,….) at the leading node of each lower level of an insignificant tree. The total numbers of these skip markers depend on the decomposition levels. The number of skip markers increases as the decomposition level increases, the proposed MELS coder does not uses any skip markers for the descendents and grand descendents of Type A or Type B sets, thereby saving the memory. Thus MELS algorithm also uses markers to mark only the states of sets/subset of trees to code the image. The pseudo code of the proposed Memory Efficient Listless SPIHT (MELS) algorithm is given in the next section. The decoder follows the same overall procedure as the encoder.

4. Result and Discussion:

In this paper we have presented for the performance assessment of the memory efficient listless SPIHT algorithm .For this purpose we have considered four different images of different size and contents. These images are then resized at a level of 64*64, 128*128, 256*256, 512*512.The different image which are considered are shown below:
1. Barbra
2. Baboon

It has been observed that CR decrease from 126.5174 to 7.9941 as we increase BPP and PSNR also found to decrease from 46.1029 to 30.9603.PSNR above than 30 is taken as good.In this way BPP above than 0.25 provides a better quality of image.

Fig .1. BARBRA Image.

Table 1. Comprasion of PSNR for Barbara image

BPP(RATE)	64*64	128*128	256*256	512*512
0.0625(PSNR)	31.9247	34.9605	38.1628	21.4433
CR	126.5174	127.6261	127.9063	127.9766
0.125(PSNR)	31.3495	33.0559	37.0183	18.5023
CR	63.6272	63.9064	63.9776	63.9941
0.25(PSNR)	31.3495	31.7903	36.5614	17.1890
CR	31.9065	31.9776	31.9941	31.9985
0.5(PSNR)	25.7524	27.0162	30.2652	10.5560
CR	15.9766	15.9941	15.9985	15.9996
1(PSNR)	23.2531	24.2656	26.7684	7.4177
CR	7.9941	7.9985	7.9996	7.999

It has been observed that CR decrease from 126.5174 to 7.9941 as we increase BPP and PSNR also found to decrease from 31.9247 to 25.2531.PSNR above than 30 is taken as good. In this way BPP above or equal to 0.25 provides better quality of compression.

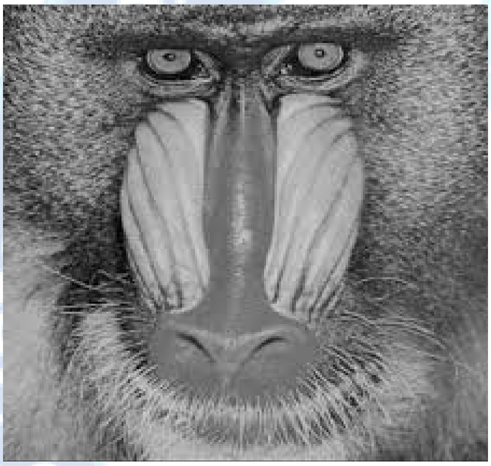

Fig. 2. Baboon Image.

Table 2. Comprasion of PSNR for Baboon image

BPP(rate)	64*64	128*128	256*256	512*512
0.0625(PSNR)	54.7052	44.8182	44.4034	44.8789
CR	126.5174	127.6261	127.9063	127.9766
0.125(PSNR)	52.5827	44.8182	42.7936	42.8113
CR	63.6272	63.9064	63.9766	63.9941
0.25(PSNR)	52.5827	44.8182	42.3699	41.9961
CR	31.9065	31.9766	31.9941	31.9985
0.5(PSNR)	45.9312	31.3020	29.1024	32.3513
CR	15.9766	15.9941	15.9985	15.9996
1(PSNR)	41.6513	27.2446	25.3006	28.2972
CR	7.9941	7.9985	7.9996	7.9999

5. Conclusion:

The conclusions are also drawn in terms of CR at the variations of bpp and image size. Since it is inherent quality of SPIHT that we can obtain desired CR at different size of image so it is observed that for all the images CR is 128 at bpp = 0.0625,64 at bpp = 0.125 ,32 at bpp = 0.25 16 and 8 times at bpp = 0.5 and 1.Hence for all images similar inferences are drawn irrespective to image types and size. However as the CR is reduced the reduction in PSNR is also observed. It can be concluded that at bpp=1 CR is lowest i.e. 8 times at this values PSNR is very low for large size images. In this way at the large level of compression of large size image there is very significant data loss due to this quality of reconstructed image degraded to an unacceptable level.

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