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SIWT-SPIHT: A Shift Invariance Wavelet Transformation based SPIHT for Image Compression

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Abstract: In this paper we review an improvised method of SPIHT (Set Partitioning in Hierarchical Trees) technique based on structural adaptability in image compression. The SPIHT variant offers subjective as well as objective efficiency and through minimum complexity of computation performs at the decoder level image reconstruction. The designed improvised method first executes a pre-processing stage called as Shifting Invariance which creates in the unchanged signed integer range, structural values for enabling reliable calculation of the evolved coefficients. The test results show the approach in comparison to contemporary SPIHT variants, enhances considerably the quality of the visuals reconstructed. The approach also performs quicker coding and efficiently manages structurally the encoded resultant bit stream to execute the decoding with malleable resolution. Thus the method creates transformed coefficient based on probability of relevance in terms of invariant materialization threshold values by developing Perspective Processing where for every context the Huffman code is generated. The scope of the model is assessed based on metrics such as PSNR (Peak Signal to Noise Ratio) and SSR (Structural Similarity Ratio) and the study outcomes demonstrate the models efficiency for malleability and robustness which show the model is an improvement over the conventional methods and is new SPIHT variant.

Key Words: Shifting invariance, SPIHT, Wavelet Transformation, perspective processing, Structural Similarity Ratio

1. INTRODUCTION

SPIHT is computationally very fast and among the best image compression algorithms known today. According to statistic analysis of the output binary stream of SPIHT encoding, propose a simple and effective method combined with Huffman encode for further compression. Wavelet transform as a branch of mathematics developed rapidly, which has a good localization property in the time domain and frequency domain, can analyze the details of any scale and frequency. so, it superior to Fourier and DCT. It has been widely applied and developed in image processing and compression. EZW stands for “Embedded Zero tree Wavelet‟. “Embedded Image Coding Using Zero trees of Wavelet Coefficients” is a simple and effective image compression algorithm, its output bit-stream ordered by importance. Encoding was able to end at any location, so it allowed achieving accurate rate or distortion. This algorithm does not need to train and require pre-stored codebook. In a word, it does not require any prior knowledge of original image. More improvements over EZW are achieved by SPIHT. SPIHT stands for “Set Partitioning In Hierarchical Trees”. In this method, more (wide-sense) zero trees are efficiently found and represented by separating the tree root from the tree, so, making compression more efficient. The image through the wavelet transform, the wavelet coefficients ‟ value in high frequency region are generally small, so it will appear serrate "0" situation in quantify. SPIHT does not adopt a special method to treat with it, but direct output. In this paper, focus on this point, propose a simple and effective shift invariant wavelet transformation (SIWT) and Predetermine perception Resolution Optimality (PPRO) method combined with Huffman encode for further compression.

2. THE PROPOSED SCHEME

2.1 The Shifting Invariance

The Shifting Invariance technique can be implemented effortlessly and can maintains the embedded coding properties in SPIHT without the requirement of complex computation. The magnitude of the structural domain is turned into bipolar which encompasses half of the maximum total absolute structural values of range $(-2^{(N-1)})$ to $(+2^{(N-1)}-1)$ if the pixel values are scaled down by $2^{(N-1)}$, where the number of original pixel in bits is represented by N. The strategy of wavelet lifting in the domain transform is based on generating a high pass sub band and low pass sub band. The high pass sub band is generated after prediction based on the pixel values specific weighted differences, whereas the low pass sub is generated following the updating step based on the pixel values weighted average. Next the low pass sub band is further decomposed by an iterative process to achieve decomposition at every level which gives a band of lowest frequency and the remaining bands are bands of high frequency.

The method of SPIHT coding is based on the technique of bit plane coding and with the changed coefficients associated maximum absolute value, finds the maximum number bit plane. The encoding and decoding time of the SPIHT algorithm is reduced since the technique of Shifting Invariance decreases the maximum coefficients. Also in the structural domain, the absolute image values in the lower side, previously in the range of $0 \le p_{i,j} \le 2^{N-1}$, in the bipolar sense are moved to higher range. The information in detail of the boundaries, edges, etc. is given by the lower image values and since these coefficients are of importance at a higher threshold value, they in the SPIHT based progressive transmission of bit streams are ordered before in the bit plane. The bipolar process involves no additional budget as the SPIHT algorithm encodes every time a sign bit for significant coefficients. Even if the process of decoding is stopped at a lower bit rate, at that rate also due to the presence some information detail, the subjective and objective nature of the quality factor is enhanced.

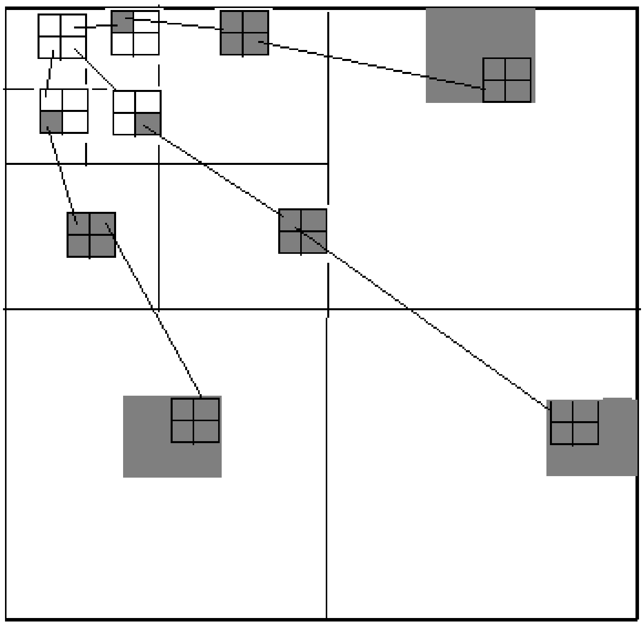

Figure 1: Point of Reference Tree in SPIHT [8]

2.2 SIWT- SPIHT

In Fig.1 the SPIHT algorithms parent dependency materialization and the related trees of Point of Reference for the decomposition at three levels are shown. The tree is characterized such that coordinates of the algorithm represent each node which in terms of the next effective level [4] has no leaves or off springs at similar structural location.

As shown in Fig. 1, the SPIHT in the original form has 2x2 blocks of adjacent pixels obtained from pixels grouped together. The pixels grouped are the tree roots available at the coarsest level such as the 3rd level of the Lower Level sub band. There is no child or offspring to the pixel in the left top corner in each block. In the first stage the LIP is stored with the coarsest level pixel coordinates coefficients and the LIS is stored as D-type sets with the coefficients coordinates having offspring's. Here the SPIHT algorithms initialization stage is changed to include the Shifting Invariance rule as in the next process. In case the level of decomposition involves the LL sub band of coarsest level with only one pixel, it is stored in the LIS list with the coarsest level coordinates such as HL, LH and HH. For instance an image of 512x512 pixel size is formed into set of levels, which are assigned the above 1/3rd coordinates where each is also a single pixel. Otherwise, the LIS list is initialized as the LIP set that contains entire coordinates of LL. Thus for LIS, in the sorting pass SPIHT initially tests the significance in the lower sub band of LH, HL and HH bands. Next the approach in LL sub band for every root performs a comparison of the maximum value amongst three other bands present at similar Point of Reference. In the output bit stream they are next sorted. The remaining descendants, after completion of the above test, are sorted into 'D' or 'L' type sets by the SPIHT [6] algorithms set partition rule. The encoder path of execution is duplicated by the decoder and at this decoder level we have complete freedom without any problems of bit budget to encode the complete bit plane. The approach is tested with images of varied types having structurally varied features and from the results we observe, compared to the original method, the same PSNR values with a faster codec is offered.

2.3 Predetermine perception dispensation

In the process of encoding considerable information of LIS and LIP is produced by the SPIHT algorithm. The redundancies of any type are supposedly not generated by LIP due to the distinct covariance inherent to it. Then considerable information of materialization is produced of 2x2 blocks when LIS of type A becomes considerable at specific threshold. Here the chance of materialization being significant is utilized, where by assigning 1 to significant coefficient and 0 to insignificant coefficient, and different possible combinations of configurations from 0000 to 1111, equalling to 16 configurations are created. Here each configuration is found, which is referred as prospect of perceptive model occurrence. The additional image compression involving a lower complexity compared to the arithmetic coding is achieved with the systematic trend found in such context's probability distribution together with Huffman coding.

2.4 Predetermine perception Resolution Optimality (PPRO)

The SPIHT algorithm because of the strategy of its bit plane coding, offers SNR or quality optimality and however in offering the resolution optimality, it is unsuccessful. In the process, two passes are used, significant pass followed by the Refinement pass for the coding of each bit plane. In an interleaved manner each pass produces as a whole the bitstream, where no differentiation is made amongst the required resolutions. The total information held by the bits of a resolution if present at a single place with the boundary of separation information of different resolutions, then for a specific resolution the decoder is able to decode an image. To collect all the information of a specific resolution at a single place, the bitstream structure is changed. For instance, according to the simulations implemented just three resolutions is shown. The SPIHT algorithm incorporation with the PPRO should also be considered. The passes have bitstream corresponding to diverse individual resolution next to each other. For the specific requisite resolution the coding of each bit plane must be split in parts where each part for the specific resolution must hold the equivalent information produced by both the passes of significance and refinement.

After the process of refinement pass for all values of threshold, the sorting pass is implemented for each resolution, and in terms of the progressive bit plane coding is stored in the output bitstream. The algorithm does the coding of the entire image beginning from the resolution 1 and produces a header which for a specific resolution carries the information of the boundary. For instance a resolution 1, the specific LIS coefficients of type A having materialization also in the resolution level 1 are only processed. In the same way LIP is processed only with the specific coefficients which are of the same resolution. The decoder is sent the header comprising of all the boundary information which is used at the decoder for the image reconstruction at a specific resolution level.

3. THE FORMAT OF CODEC

The SPIHT algorithm processes the wavelet transformed coefficient by coding in a bit plane style and the significant information in terms of the given threshold and its sign, is given as outputs. In this study the original image is considered to have N number of bits and the pixel values are pre-processing by shifting downwards by 2^{N-1} and on it later the 2D wavelet is implemented. Next utilizing a 2D SPIHT coder the transformed coefficient is encoded (see fig 2).

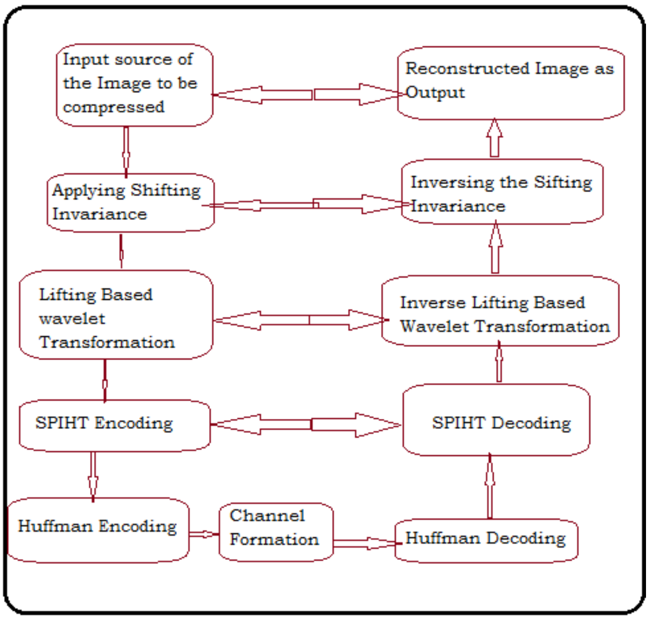

Figure 2: Shifting Invariance based Format of the CODEC projected

The original image is reconstructed in the decoder, by duplicating the execution path of the encoder and shifting upwards by $2^{(N-1)}$ the values of inverse transformed coefficients.

4. RESULTS AND DISCUSSION

4.1 Quality Measurement Metrics

The image in the reconstruction process undergoes extensive distortion in the compression process described above. The visual image quality, that's inconvenient, time consuming, and complex is emphasized in subjective evaluations. The metrics like, PSNR (Peak Signal to Noise Ratio), or MSE (Mean Squared Error) and SSR (Structural Similarity Ratio) [2] of objective image quality in image processing application process are regarded most effective.

The commonly used MSE metric, is well defined in the physical interpretation, is mathematically suitable and easy in calculation. The square of the intensity difference of reconstructed image x, and the original image, x is averaged to compute MSE. Next the result is used to compute PSNR. The mathematical representation is described as below,

$$MSE = \sum_{x=1}^{W}\sum_{y=1}^{H}[si(x,y) - dci(x,y)]^2 \quad (1)$$

Here in above equation, the 'W' is width and 'H' is height of the source image si and resultant decomposed image dci, x and y are coordinates in the range 1 to W and 1 to H respectively. The grey image size is considered as byte per pixel. Henceforth the maximum fluctuation in source image si is 255. Then the PSNR can be measured as follows:

$$PSNR = 20\log_{10}\frac{255}{\sqrt{MSE}} \quad (2)$$

In terms of human visual perception however it is not correctly matched. The study in paper [2] shows the visual quality for two reconstructed images varies at varying rate considering the same $PSNR$ values. This is so since the natural images pixels show strong dependencies and very high structural properties. The similarity measurement task is separated into three comparisons such as, luminance, contrast, and structure by the SSR system. The definition of the overall similarity measure is [2,17] is as below,

$$S(si,dci) = f(l(si,dci), c(si,dci), s(si,dci)) \quad (3)$$

Here the original image presumed as totally perfect is represented as si and the reconstructed image is represented as dci , so that the two images are non-negative images, where S=1 means the images have perfect similarity. The function $l(si,dci)$ is the function of the mean of si and dci values that represents luminance comparison, the '$c(si,dci)$' is the standard deviation function of si and dci that represents the contrast comparison and $S(si,dci)$ represents the structure comparison function.

4.2 Time Complexity of the projected encoding and decode process

The implementation of the approach is shown practically with experiments done on imageJ and expression language R. The Tests executed are done with the benchmark images [31]. The two type of filters popularly used in image compression applications, 'Wavelet Biorthogonal filter' and 'Cohen-Daubechies-Feauveau wavelet' with half point symmetry at the boundary are used. The tests are performed using systems with, PIV, 2.4 GHz, 2 GB RAM configurations.

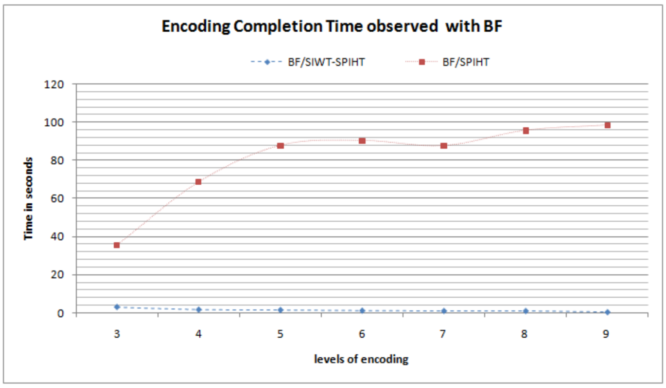

Figure 3: Encoding time (in seconds) observed with SPIHT and SIWT-SPIHT under Biorthogonal Filter

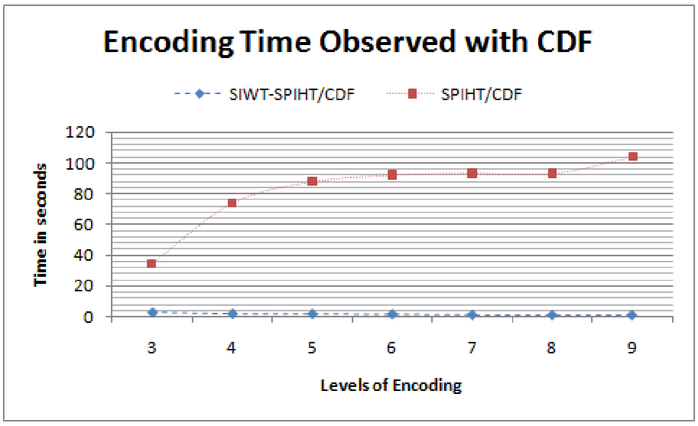

Figure 4: Encoding time (in seconds) observed with SPIHT and SIWT-SPIHT under Cohen-Daubechies-Feauveau filter

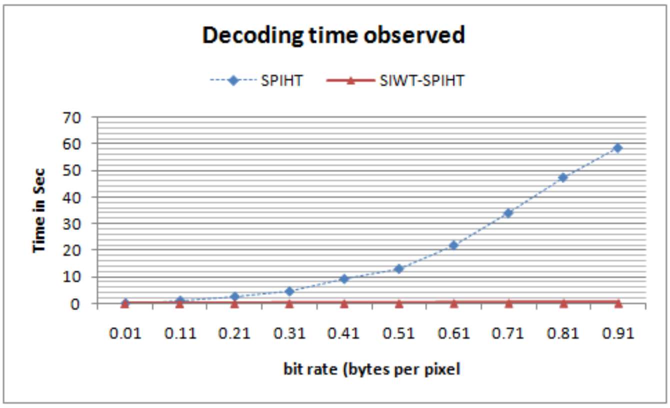

Figure 5: Decoding time (in seconds) observed for SPIHT and SIWT-SPIHT

The experimental results shown with the modified algorithm, the codec becomes faster regardless of the filter type used i.e. the time of encoding is considerably decreased and compared to the original approach, the time taken is in the range of 10% to 90% less. This encoding time remarkably decreases with increase in number of decompositions in the range of 3 to 9 on images of resolution 512X512 in steps of 1, however in case of the original, the time increases practically linearly (see fig 3 and 4). If we use the Shifting Invariance method, the time taken for encoding with the original algorithm is greater than that without the pre-processing steps involved. In case of the modified algorithm, for the level 5 and above, the encoding time is practically constant. Hence in case of other experiments, involving the modified algorithm, if not mentioned differently, the image is structurally decomposed for 8 levels. An experiment is performed subsequent to the validation of the encoding time complexity, to confirm the quality of the reconstructed image with the projected Shifting Invariance method. The reconstructed image values of PSNR and SSR at different bit rate is recorded.

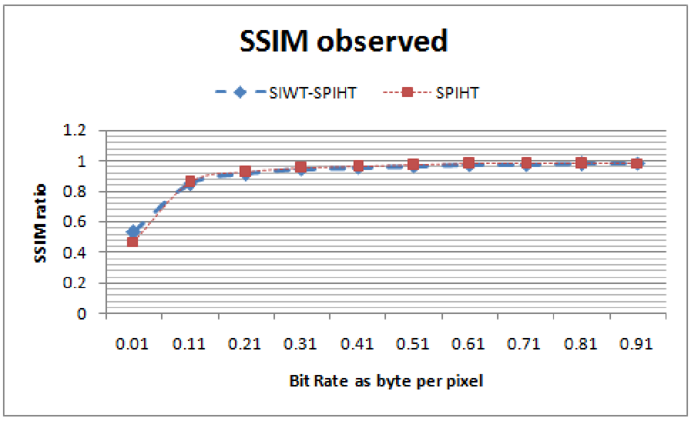

Figure 6: SSIM observed for SPIHT and SIWT-SPIHT

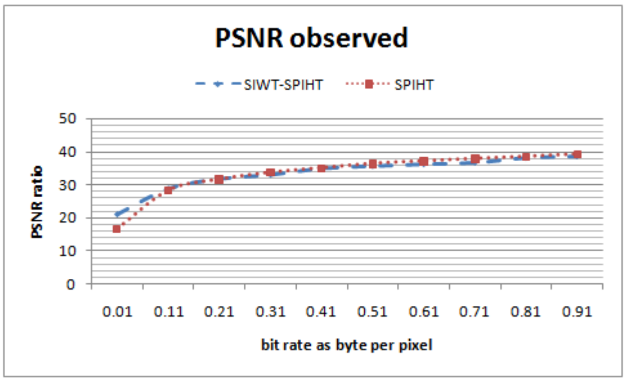

Figure 7: PSNR observed for SPIHT and SIWT-SPIHT

The observations are, the image is encoded for the entire bit plane in case of the modified algorithm, which however is limited to the given bit budget in case of the original algorithm. Nonetheless in case of the modified algorithm encoding is feasible with the constraints of the same bit budget. If we observe both the tables, obviously the decoding is faster in case of the approach of modified algorithm. The modification in the initialization of the image pixel coordinate results in an enhanced objective metric like PSNR and so as in the scanning process also. We also see in case of the original algorithm at some bit rate the SSR metric is efficient. Here the tests are executed with ‘Wavelet Biorthogonal filter’ at level 6 of structural decomposition.

5. CONCLUSION

In this paper, we presented a novel extension of wavelet based SPIHT coding scheme called "A Shift Invariance Wavelet Transformation based SPIHT for Image Compression (SIWT-SPIHT". The objective of the proposed model is Prior to wavelet transformation initiated, the pixel value processing takes place and shift invariant set of unsigned integers will be formed towards wavelet transformation.. The metrics like PSNR, SSIM, compression ratio, Time Complexity of encode and decode are explored to assess the scalability and robustness of the SIWT-SPIHT. The explored empirical study concluding that the proposed model is magnitude faster compared to traditional SPIHT strategy towards encode and decode process without losing the quality of the process. The model devised here in this paper is an extended version of the traditional SPIHT strategy. The significant change recommended to the existing model is at bit stream encoding. The extended version facilitate to pause the bit stream to optimize the bit rate during encode and decode process. To achieve minimal computational complexity, a novel perception strategy is devised to simplify the coding process at different resolutions. The said perception strategy devised is based on Huffman coding. The explored results are motivating us to extend this model further to achieve scalable and robust encoding and decoding strategies for domains such as spatial images and visual media.

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