ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, Vol 8(34), DOI: 10.17485/ijst/2015/v8i34/74365, December 2015 ISSN (Online) : 0974-5645

Efficient Lossless Image Compression Using Modified Hierarchical Prediction and Context Adaptive Coding

P. Suresh Babu* **and S. Sathappan**

Department of Computer Science, Erode Arts and Science College, Erode - 638009, Tamil Nadu, India; sureshbabuphdresearch@gmail.com, devisathappan@yahoo.co.in

Abstract

Objective: The main intention of this research is to protect the sharpness of image through decreasing the bit rates in compression image. The proposed approach also intends to improve the compression ratio by predicting the diagonal pixels along with the horizontal and vertical pixels of the image. **Methods:** In this research, Modified Hierarchical Prediction and Context Adaptive (MHPCA) coding is introduced to overcome the issue of enormous prediction error rate near edges and preserves the sharpness of images. MHPCA coding scheme considers the vertical, horizontal and diagonal (left up, left down and right up, right down) predictors to predict pixels of the image. The inclusion of diagonal predictor enhances the prediction accuracy of pixels in hierarchical prediction. **Findings:** The experimental tests of MHPCA are conducted and the performance is compared with the existing HPCA scheme which proves that the proposed methodology can preserve the sharpness of the image in an efficient manner than HPCA method. The comparison results prove that the proposed methodology is also efficient in terms of performance metrics such as Bits per Pixel (BPP), Compression Ratio, Mean Square Error rate (MSE) and Peak Signal to Noise Ratio (PSNR). **Application/Improvement:** The findings demonstrate that by using proposed MHPCA scheme the bit rates in compressed images are reduced significantly which preserves the sharpness of the image. MHPCA coding scheme also reduces the error rate considerably and produces higher compression ratio than the existing HPCA scheme.

Keywords: Context Adaptive Coding, Lossless Color Image Compression, Modified Hierarchical Prediction

1. Introduction

Lossless compression technique produces an efficient algorithm to compress the image without loss of information. JPEG standard consist of lossy and lossless compression techniques with several modes of operation. In general JPEG features is a straightforward lossy method recognized as the Baseline scheme, a separation of the other DCT based modes of operation. Yet the transmission cost of JPEG lossy compression technique is high and the amount of information is also lost[1]. JPEG 2000 is a lossless mode which is utilized for bit-preserving and also used to refer globally for encoding and decoding processes. The JPEG 2000 files layout provides a base for accumulating application exact data (metadata) in association with a JPEG 2000 codestream, such as information which is essential to present the image. An invertible version of color transform, the reversible color transform (RCT) is utilized in JPEG 2000[2].

To show high bit range images on low bit resolution displays, bit resolution requires to be minimized. The preceding researchers are suggested various algorithms such as Lossless JPEG, JPEG-LS and so on. The color components are decorrelated through the color conversion and the image compression is ensured. Every component transformation is separately compressed through above mentioned algorithms. In lossless firmness, various approaches of prediction are depends on the raster search calculation which is in frequently unproductive at the high frequency section. To determine this problem, the preceding research used hierarchical prediction design which consists of edge directed forecaster and context

* *Author for correspondence*

adaptive system[3]. The hierarchical prediction proceeds in arbitrary order and reconstruction of the image is done from the lowest level of resolution level to the highest[4,11].

The hierarchical prediction is extensively used for diversity of purpose in the image compression. Hierarchical prediction is used for pixel interpolation and it is most efficient decorrelation scheme. In Hierarchical prediction based image compression, the image is divided into odd image and even image. There are two types of predictors named as horizontal or vertical predictors. If predicted value of vertical predictor is less than horizontal predictor then vertical predictor is used otherwise horizontal predictor is used. This hierarchical prediction method reduces the bit rates than JPEG2000 and JPEG-XR schemes. The average bit rates are reduced from 0.3 to 1 than JPEG2000 and JPEG-XR. In this scenario the hierarchical prediction is modified by include the prediction of diagonal pixels which increase the prediction accuracy.

In existing research LOCO-I (Low Complexity Lossless Compression for Images) has been introduced for proficient image compression[5,12]. Such kind of method is utilized for lossless and near-lossless compression of continuous-tone images in JPEG-LS. It is based on fixed or adaptive context mode and here the method is adjusted for proficient achievements. In favor of various color spaces (e.g., an RGB image), high-quality decorrelation could be achieved via easy lossless color transforms as a pre-processing step to JPEG-LS. In case of LOCO-I is a fixed predictor which performs a primitive test to detect vertical or horizontal edges. It defines the left, right, upper and lower pixel prediction based on the vertical or horizontal edges. This prediction is used to perform smoothness of images in the absence of edges. This research algorithm accomplishes prominently improved compression ratio, higher to other methods based on adaptive coding. In this kind of algorithm, the lesser entropies are accomplished through superior perspectives. It has been executed with percentage points of optimal compression ratios in lesser convolution stage. Complexity is evaluated by measuring the running times. However in the place of large errors the future values are gets affected in this method.

Feature of CALIC (Context-based, Adaptive, Lossless Image Coding) is an adaptive which means gradient adjusted and context based i.e. refinement. It comes under the lossless compression technique. The main aim of the CALIC is producing error feedback through which learning from its mistakes under a given context in the previous. It is obtained 2% lower bit rate and increases the sharpness of an image[6]. JPEG 2000 is established for continuous-tone still images, both grayscale and color. It is extremely useful and suitable for many real time applications. Reversible Color Transform (RCT) is capable of lossless compression and it might be used in reduced codestreams to provide lossy compression. As mentioned earlier for color image compression each input image has three colors per pixel. In lossy technique the RGB to Y C_bC_r is used whereas in lossless compression the lifting approach is used frequently. From the direct transform matrix that optimal lossless compression performance can obtained[7]. This JPEG compression is very useful in providing low resolution level versions of all image components at a particular spatial location. Yet in some cases it is too slow by means of compression and decompression for digital cameras.

To achieve high image quality with low computational resources another method is used which is called as JPEG XR. JPEG committee introduces this new image coding scheme which is mainly targeted on continuous-tone still images like photos. In this architecture the input image is operated by encoder which builds a JPEG XR coded image. The decoder operates on the image and produce output that will be an appropriate or exact reconstruction of input. While using JPEG, tone mapping and other adjustments should be concerned before encoding. In case of JPEG XR tone mapping and adjustments will be done on the image only after encoding and decoding. Due to this way of process we can frequently observe the quality degradation. Hence it is efficiently performing the high dynamic range images with minimum storage cost[8].

A color space is an arithmetical representation of a set of colors. The top most colors are Red, Green and Blue (RGB) which is utilized in the computer graphics. All color spaces can be resultant from the RGB information applied by devices such as cameras[7]. In case of lossless compression many color transforms could not be able to apply owing to their non-invertibility through integer arithmetic. The invertible color transforms and reversible color transform is exploited by JPEG 2000[2]. The hierarchical prediction is developed for predicting the pixels rather than raster scan prediction method.

2. Hierarchical Prediction and Context Adaptive (HPCA) Coding

This research introduces novel lossless color picture compression algorithm which depends on HPCA system. To achieve the lossless picture compression, the image is de-correlated using RCT. Figure 1 demonstrates the contribution image and its disintegration.

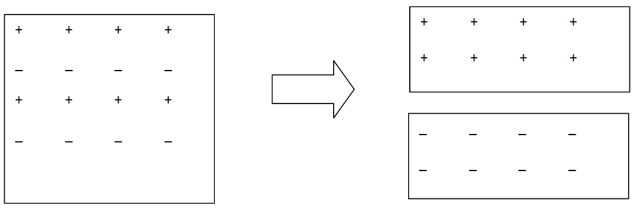

Figure 1. Input picture and its disintegration.

HPCA makes easy the exploit of left, upper and lower pixels for the pixel prediction. At first the hierarchical decomposition decomposes the input images into even subimage and odd subimage. Even sub-image is represented by X_e and odd subimage is denoted by X_o. Then, X_e is encoded first and is used to predict the pixels in X_o. Additionally X_e is used for estimating the information of prediction errors of X_o. Directional prediction is used to avoid huge error prediction near the edges in the compression of odd subimage X_o via X_e.

For all pixel x_o (i,j) in X_o horizontal predictor $\widehat{x_h}(i,j)$ and vertical predictor $\widehat{x_v}(i,j)$ are described as follows and one of them is chosen as a predictor for X_o (i, j).

$$\widehat{x_h}(i,j) = X_o,(i,j\text{-}1)$$

$$\widehat{x_v}(i,j) = \text{round}\frac{x_e(i,j)+x_e(i+1,j)}{(2)} \quad (1)$$

Vertical predictor is frequently chosen instead of the horizontal predictor and also upper as well as lower pixels are used for vertical predictor. For maximum pixels the vertical predictor is applicable for accurate prediction. Adaptive arithmetic code is used for determining and encoding the prediction error[9]. This method yields reduction of bit rates in compression image output. Pixel reordering concept is used for achieving the efficient and effective lossless image compression[10].

<u>Algorithm 1</u>:

if $\left|X_o(i,j)-\widehat{x_h}(i,j)\right|+T_1<\left|X_o(i,j)-\widehat{x_v}(i,j)\right|$ then
dir(i,j) ←H
else
dir(i,j) ←V
end if

<u>Algorithm 2</u>:

If dir (i-1,j)=H or dir(i,j-1)=H then
Compute dir(i,j) by algorithm 1
Encode dir(i,j)
If dir(i,j) = H then

$$\widehat{x_o}(i,j) \leftarrow \widehat{x_h}(i,j)$$

Else

$$\widehat{x_o}(i,j) \leftarrow \widehat{x_v}(i,j)$$

End if
Else
$\widehat{x_o}(i,j) \leftarrow \widehat{x_v}(i,j)$
Compute dir(i,j) by algorithm 1
End if.

3. Modified Hierarchical Prediction and Context Adaptive (MHPCA) Coding

To preserve the sharpness of original image and to reduce the bit rates we propose a new scheme is called as Modified Hierarchical Prediction. By using this scheme the vertical, horizontal, diagonal (left up, left down and right up, right down pixels) pixels are predicted to progress with the compression process. Initially the chrominance image is divided row by row into even subimages and odd subimages.

For all pixel X_o (i,j) in X_o, diagonal predictor $\widehat{x_d}(i,j)$ are described as follows and one of them is chosen as a predictor for X_o (i, j).

$$\widehat{x_d}(i,j) = \text{round}\left(\frac{x_e(i+1,j-1)+x_e(i-1,j-1)+x_e(i-1,j+1)}{2}\right) \quad (2)$$

The predicted image is determined by the horizontal, vertical and diagonal pixels. Using diagonal predictor we can predict the correct predicted image. The even subimage is again divided column by column into even subimage and odd subimage. $X_o^{(2)}$ Odd subimage is compressed through which even subimage $X_o^{(2)}$ is generated. This compression images are usually high quality with sharpness and while the decompression we again apply the left up, left down and right up, right down pixels predication. We can preserve the sharpness of original image using Modified Hierarchical Prediction.

The new scheme produces very low prediction error in the compression image. The mean square error rate is calculated and bit rate is reduced significantly by using the Modified Hierarchical Prediction.

Proposed Algorithm 1

if $\left(\left(\left|X_o(\mathrm{i,j})-\widehat{x_h}(\mathrm{i,j})\right|+T_1<\left|X_o(\mathrm{i,j})-\widehat{x_v}(\mathrm{i,j})\right|\right)\&\&\left(\left|X_o(\mathrm{i,j})-\widehat{x_h}(\mathrm{i,j})\right|+T_2<\left|X_o(\mathrm{i,j})-\widehat{x_d}(\mathrm{i,j})\right|\right)\right)$ then

dir(i,j) ←H
else if $\left(\left(\left|X_o(\mathrm{i,j})-\widehat{x_v}(\mathrm{i,j})\right|+T_1<\left|X_o(\mathrm{i,j})-\widehat{x_h}(\mathrm{i,j})\right|\right)\&\&\left(\left|X_o(\mathrm{i,j})-\widehat{x_v}(\mathrm{i,j})\right|+T_2<\left|X_o(\mathrm{i,j})-\widehat{x_d}(\mathrm{i,j})\right|\right)\right)$ then

dir(i,j)←V
else
dir(i,j)←D
end if

Proposed Algorithm 2

If dir (i-1,j)=H or dir(i,j-1)=H than
Compute dir(i,j) by algorithm 1
Encode dir(i,j)
If(dir(i,j) = H than
$\widehat{x_o}(\mathrm{i,j})\leftarrow\widehat{x_h}(\mathrm{i,j})$
else if (dir(i,j) = V than
$\widehat{x_o}(\mathrm{i,j})\leftarrow\widehat{x_v}(\mathrm{i,j})$
else
$\widehat{x_o}(\mathrm{i,j})\leftarrow\widehat{x_d}(\mathrm{i,j})$
End if
Else if dir (i,j)=V or dir(i+1,j)=V
Compute dir(i,j) by algorithm 1
Else if dir (i+1,j-1)=D or dir (i-1,j-1)=D or dir (i-1, j+1)=D than
Compute dir(i,j) by algorithm 1
End if

4. Results and Discussion

In this section the performance metrics are compared among existing and proposed scenarios by using efficient methodologies. The performance metrics are considered as Bits Per Pixel (BPP), Compression Ratio, Mean Square Error rate (MSE) and Peak Signal to Noise Ratio (PSNR). The existing Hierarchical Forecast and Context Adaptive System and proposed Modified Hierarchical Forecast Scheme are used to estimate the above mentioned performance metrics. Both of these methods are used to improve the performance of image compression. From the experimental result we can conclude that proposed methodology is used to preserve the sharpness of specified image rather than existing methodology. Hence proposed Modified Hierarchical Forecast Scheme is superior in preserving the sharpness of image.

4.1 Bits Per Pixel (BPP)

BPP is described as the numeral of bits per pixel in a specified image. The amount of diverse colors in an image is related on the depth of color or bits per pixel.

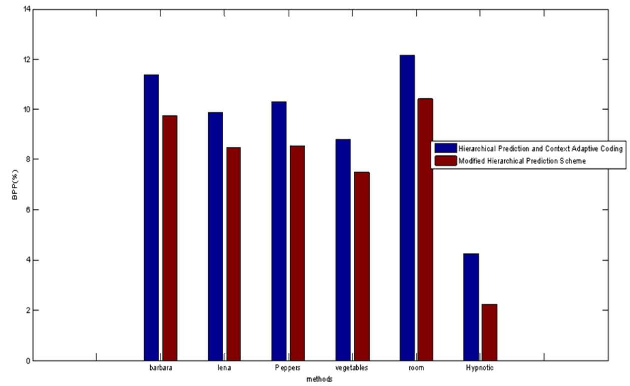

Figure 2. BPP.

From the Figure 2 it can be proved that the proposed method produces better result than the preceding approach with reduced the BPP rate. In this graph, names of images are plotted in the x axis and the BPP values are plotted in the y axis. The BPP value is high by using the existing method of HPCA coding. The BPP value is significantly reduced for all images by using proposed method of MHPCA coding. From the experimental result we can conclude that proposed method is superior to existing approaches in terms of BPP.

Table 1 shows the BPP values for existing and proposed methods. From the table values it is clear that the proposed scenario yields lower BPP values than the existing scenario.

Table 1. BPP values

Images	Hierarchical Prediction and Context Adaptive Coding	Modified Hierarchical Predictive Scheme
Barbara	11.7	8.9
Lena	10	8.2
Peppers	10.4	8.2
Vegetables	9	7.8
Room	12.1	10.1
Hypnotic	5	2

4.2 Compression Ratio

Compression ratio is described as the ratio of an original image and compressed image.

$$\text{Compression Ration}(\%) = 100 - \left[\frac{\text{Compression Image}}{\text{Original Image}} \times 100\right]$$

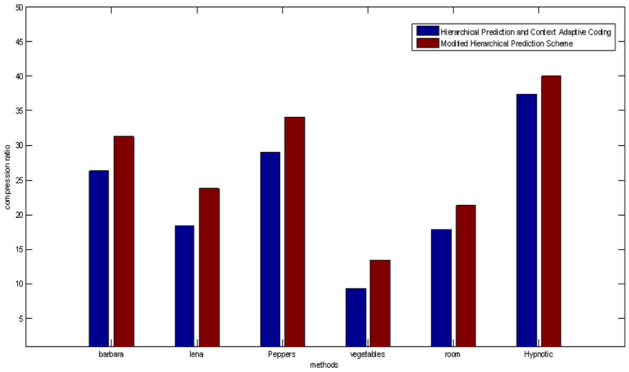

Figure 3. Compression Ratio.

From the Figure 3 it can be proved that the proposed approach produces better result than the preceding approach with increased compression ratio. In this graph, names of images are plotted in the x axis and the compression ratio values are plotted in the y axis. The compression ratio value is low for the existing method of HPCA coding. The compression ratio value is significantly increased for all specified images by using proposed method of MHPCA coding. From the experimental result we can conclude that proposed method is superior to existing system in terms of compression ratio.

The Table 2 shows the compression ratio values for existing and proposed methods. From the table values it is clear that the proposed scenario yields highest compression ratio values than the existing scenario.

Table 2. Compression Ratio

Images	Hierarchical Prediction and Context Adaptive Coding	Modified Hierarchical Predictive Scheme
Barbara	27	33
Lena	19	24
Peppers	29	35
Vegetables	10	15
Room	19	22
Hypnotic	38	41

4.3 Mean Square Error (MSE)

MSE computes the average of the squares of the errors from an image.

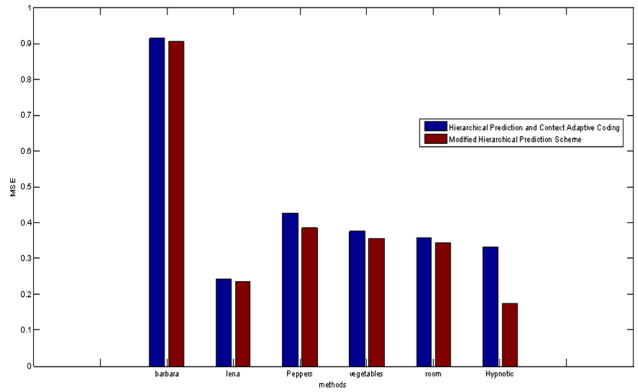

Figure 4. MSE.

From the Figure 4 it can be proved that the proposed approach produces better result than the preceding approach with reduced MSE rate. In this graph, names of images are plotted in the x axis and the MSE values are plotted in the y axis. The MSE value is high by using the existing method of HPCA coding. The MSE value is significantly reduced for Baboon and Peppers images by using proposed method of MHPCA coding. From the experimental result we can conclude that proposed method is superior to existing approaches in terms of MSE.

Table 3 shows the MSE values for existing and proposed methods. From the table values it is clear that the proposed scenario yields lower MSE values than existing scenario.

Table 3. MSE values

Images	Hierarchical Prediction and Context Adaptive Coding	Modified Hierarchical Predictive Scheme
Barbara	0.91	0.89
Lena	0.25	0.24
Peppers	0.45	0.4
Vegetables	0.39	0.36
Room	0.36	0.35
Hypnotic	0.32	0.19

4.4 Peak Signal to Noise Ratio (PSNR)

Peak Signal to Noise Ratio is defines that the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation.

From the Figure 5 it can be proved that the proposed approach produces better result than the preceding approach with increased PSNR rate. In this graph, names of images are plotted in the x axis and the PSNR values are plotted in the y axis. The PSNR value is lower by using the existing method of HPCA coding. The PSNR value is significantly improved by using proposed method of MHPCA coding. From the experimental result we can conclude that proposed method is superior to existing system in terms of PSNR.

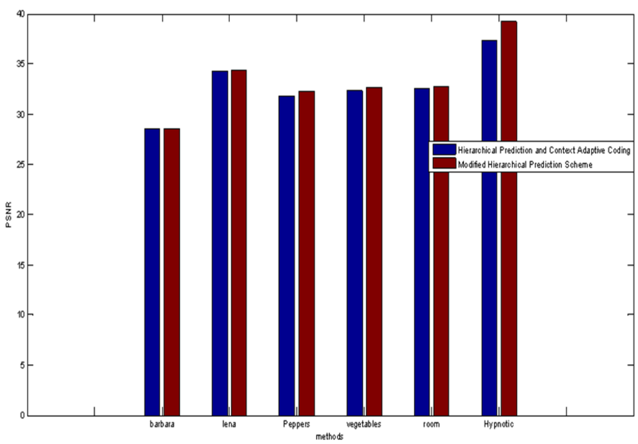

Figure 5. PSNR.

Table 4 provides comparison of existing and proposed methods in terms of PSNR. From the table values it is clear that the proposed scenario yields higher PSNR values compare than existing scenario.

Table 4. PSNR values

Images	Hierarchical Prediction and Context Adaptive Coding	Modified Hierarchical Predictive Scheme
Barbara	28	28.1
Lena	34.7	34.8
Peppers	32	33
Vegetables	33	33.39
Room	32	32.1
Hypnotic	36	39

5. Conclusion

Modified Hierarchical Prediction and Context Adaptive (MHPCA) coding scheme is proposed in this paper. The proposed method preserves the sharpness of the image and achieves high compression ratio when compared with existing approaches. MHPCA also provides high PSNR value and low error rate. MHPCA performs well on lossless image compression but in future work variable sized image blocks can be used to reduce "blocking" effects, and also large image blocks can be used which will provide higher compression ratios for the uniform dark regions in the surroundings of the images.

6. References

1. Wallace KG. The JPEG Still Picture Compression Standard, in Communications of the ACM. Special issue on digital multimedia Systems. Maynard, Massachusetts. 1991; 34(4):30–44.
2. Information technology – JPEG 2000 image coding system: Core coding system. Available from: https://www.ic.tu-berlin.de/fileadmin/fg121/Source-Coding_WS12/selected-readings/20_T-REC-T_1_.800-200208-I__PDF-E.pdf
3. Seyun K, Cho NI. Hierarchical prediction and context adaptive coding for lossless color image compression. IEEE Transactions on Image Processing. 2013; 23(1):445–9.
4. Weinberger MJ, Seroussi G, Sapiro G. The LOCO-I lossless image compression algorithm: Principles and standardiza¬tion into JPEG-LS. IEEE Transactions on Image Processing. 2000; 9(8):1309–24.
5. Weinberger MJ, Seroussi G, Sapiro G. LOCO-I: A low complexity lossless image compression algorithm. Proceedings Data Compression Conference. 1996; 203(4):140–9.
6. Wu N, Memon N. Context-based, adaptive, lossless image coding. IEEE Transaction Communications. 1997; 45(4):437–44.
7. Malvar HS, Sullivan GJ, Srinivasan S. Lifting-based reversible color transformations for image compression. Proceedings SPIE. 2008; 47(22):707307.
8. ITU-T and ISO/IEC, JPEG XR Image Coding System - Part 2: Image Coding Specification. ISO/IEC Standard. 2011; 29199(2):195–9.
9. Said A. Arithmetic coding, in Lossless Compression Handbook. In: Sayood K, editor. San Diego, CA, USA: Academic; 2003. p. 101–52.
10. Ciavarella M, Moffat A. Lossless image compression us¬ing pixel reordering. Proceedings of the 27th Austral-asian Conference on Computer Science, Australian Conference on Computer Society. 2004; 26 (4):125–32.
11. Banu Masoodhu NM, Sujatha S. 3D medical image compression: A review. Indian Journal of Science and Technology. 2015; 8(12):56231.
12. Lee GH, Ko SW, Kwon ST. A study on the differential compression method for high speed transfer. Indian Journal of Science and Technology. 2015; 8(2):524–7.