Image Compression Using Hierarchical Prediction

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***Abstract*—With the increasing demand for digital multimedia, there has been more and more interest in visual communication over internet and wireless networks. The amount of Visual data is huge, while the bandwidth of transmission channel is limited. There is requirement to develop a Compression technique. The compression of an image using Hierarchical Prediction structure for high frequency regions improves its coding efficiency and temporal scalability. The hierarchical structure also enables more accurate context modeling of pixels by using surrounding pixels that are already encoded and used for pixel interpolation. As Hierarchical Predication can extensively be used for diversity of purposes in the image compression for high frequency regions, our objective here is to apply it to preserve the sharpness of the image with less computational overhead and time with considerably reducing the bits per pixel value. Additionally, in order to achieve high compression ratios hierarchical prediction and modified hierarchical prediction method are used.**

***Keywords*—Lossless image compression, Hierarchical prediction, Modified Hierarchical prediction, Pixel interpolation, context adaptive arithmetic coding.**

I. Introduction

The data compression becomes significant for reducing data redundancy, so can save more hardware space and transmission bandwidth. Image compression coding stores the image into bit-stream as less as possible and displays the decoded image exactly. Image compression is encoding the original image with few bits. When the encoder receives the original image file, the image file will be converted into a series of binary data. The decoder then receives the encoded binary data and decodes it to form the decoded image. If the total data quantity of binary data is less than that of the original image, this is called image compression.

Nowadays images are acquiring a broad audience. Digital cameras are used most of the time. When there is a need for transferring the image and also storing the image then problem is created. Initiative of digital images has raised the memory required for the storage and processing in today's digital era. Because of the larger size of digital images time required is more in the transmission process so that it is very important to compress the images in order to improve the processing time of larger images. The main goal of compressing images is to transmit the image with inferior bandwidth by reducing the number of pixels and to store the image with lesser memory space instead of alternating the quality of the image.

Digital images are formed of various pixel values. In the digital image Pixels of neighborhood are correlated so that this pixel contain redundant bits and by using the compression algorithms these redundant bits are removed from the image due to that the image size is lessened and the image is compressed. Decreasing the irrelevance or redundancy of an image is providing the facility for storing and transmitting the data in an useful manner [14].

The basic flow of image compression is illustrated in Fig 1. The image is given to the encoder which transforms the image into bit streams [11]. When the decoder gets these encoded bit streams it decodes it and the resultant image is obtained from the output of the decoder. Image compression occurs when the overall data quantity of the input image is greater than that of the received bit stream.

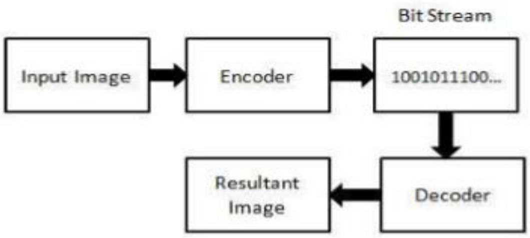

Fig:1 Basic Flow of Image Compression[11]

There are two types of image compression techniques, lossy compression technique and lossless compression technique. The lossy compression technique achieves high compression ratio at the cost of image quality degradation and in this technique considerable amount of information is lost. In Lossless compression technique there is no lost of information. Lossless compression method is used for highly sensitive applications scientific researches, health diagnosis and where the loss of a single element of an image may result in major problem.

The Lossless compression method is capable of reconstituting the original form of the data. The quality of the data is not compromised. This technique allows a file to restore its original form. Lossless compression can be applied to any file format can improve the performance of the compression ratio.

Hierarchical prediction is a lossless image compression technique. There are many existing prediction methods used for the lossless compression but they are all based on the raster scan prediction method which is inefficient for some cases, especially for high frequency regions. The hierarchical prediction is extensively used for diversity of purposes in the image compression.

Hierarchical Prediction structure provides:

i. Coding Efficiency

Coding efficiency is a term broadly used to depict the reliability, speed and programming methodology used in developing codes for an application. The speed of runtime execution of the softwareis an important element in ensuring high performance, and it directly links to algorithmic efficiency.Reduction in resource consumption and execution time as much as possible is the goal of coding efficiency, ultimately minimizing the risk to operating environment. [15]

ii. Temporal Scalability

Temporal scalability refers to the ability of reducing the frame rate of an encoded bit stream by dropping packets, helping reduce the bitrates of the stream. A video bit stream is known as temporal scalable when parts of the stream can be removed in a way that the resulting substream forms another valid bit stream for some target decoder, and the substream represents the source content with a frame rate that is smaller than the frame rate of the complete original bit stream.[16]

II. HIERARCHICAL PREDICTION AND CONTEXT ADAPTIVE (HPCA) CODING.

Hierarchical Prediction and Context Adaptive (HPCA) Coding method can use lower row pixels as well as the upper and left pixels for the prediction of a pixel to be encoded. For the compression of color images, the RGB is first transformed to YCuCv by an RCT mentioned in [9], and Y channel is encoded by a conventional grayscale image compression algorithm. In the case of chrominance channels (Cu and Cv), the signal variation is generally much smaller than that of RGB, but still large near the edges. For more accurate prediction of these signals, and also for accurate modeling of prediction errors hierarchical scheme is used: the chrominance image is decomposed into two subimages; i.e. a set of even numbered rows and a set of odd numbered rows respectively.

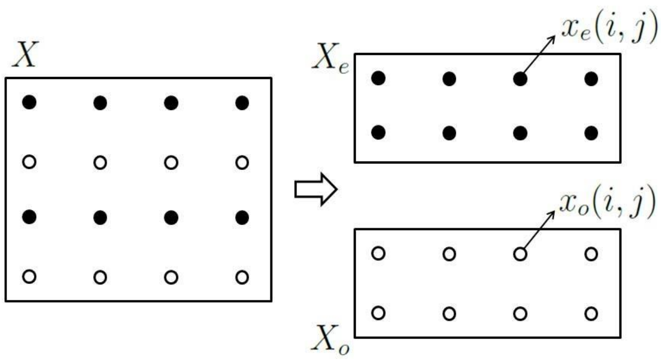

Fig:2 Input image and its decomposition.[1]

Fig.2 shows that pixel in an input image X is separated into two subimages, an even subimage Xe and an odd subimage Xo. Then, Xe is encoded first and is used to predict the pixels in Xo. For the compression of Xo pixels using Xe, directional prediction is employed to avoid large prediction errors near the edges. For each pixel xo(i, j) in Xo, the horizontal predictor xh(i, j) and vertical predictor xv(i, j) are defined as follow.

$$xh(i, j) = xo(i, j-1) \qquad (1)$$

$$xv(i, j) = \mathrm{round}\left[\frac{xe(i,j)+xe(i+1,j)}{2}\right] \qquad (2)$$

One of them is selected as a predictor for xo(i, j). With these two possible predictors, the most common approach to encoding is "mode selection," where better predictor for each pixel is selected and the mode (horizontal or vertical) is also transmitted as side information. However, the vertical predictor is more often correct than the horizontal one because upper and lower pixels are used for the "vertical" whereas just a left pixel is used for the "horizontal." The horizontal predictor is more accurate only when there is a strong horizontal edge [1].

For implementing this idea, a variable for the direction of edge at each pixel dir(i, j), which is given either H or V. Actually, it is given H only when the horizontal edge is strong, and given V for the rest. Deciding dir(i, j) is summarized in Algorithm 1, where it can be seen that the direction is given H only when |xo(i, j)− xh(i, j)| is much smaller than |xo(i, j)−xv(i, j)| by adding a constant T1 to the former when comparing them. Based on the directions of pixels, the overall prediction scheme is summarized in Algorithm 2. It can be seen that the mode selection is tried when more than one of dir(i−1, j) or dir(i, j −1) are H, and the vertical prediction is performed for the rest.

Algorithm: 1

```
if |x_o (i, j) - x_h (i, j)| + T1 < |x_o (i, j) - x_v (i, j)|
then dir (i, j) <-H
else
dir( i,j) <-V
 end if
```

Algorithm: 2

```
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
x_o (i,j) <- x_h (i,j)
else
x_o (i,j) <- x_v (i,j)
end if
else
x_o(i,j) <- x_v(i,j)
Calculate dir (i, j) by algorithm 1
end if
```

A. Proposed Hierarchical Prediction and Context Adaptive (HPCA) Coding.

For the compression of images, the RGB image is first transformed to YCuCv by reversible color transform method. Luminance channel Y is also encoded by Hierarchical decomposition scheme. The chrominance channels Cu and Cv resulting from the RCT usually have different statistics from Y, and also different from the original color planes R, G, and B. For encoding chrominance channels (Cu and Cv) hierarchical prediction method is used.

Hierarchical Prediction and context adaptive coding makes easy uses left, upper and lower pixels for the pixel prediction. For the efficient lossless compression a hierarchical decomposition scheme is used. Pixels in an input image the luminance and the chrominance image X is separated into two subimage: an even subimage Xe and an odd subimage Xo. Then, Xe is encoded first and is used to predict the pixels in Xo. For the compression of Xo pixels using Xe, directional prediction is employed to avoid large prediction errors near the edges.

III. MODIFIED HIERARCHICAL PREDICTION AND CONTEXT ADAPTIVE (MHPCA) CODING

Modified Hierarchical Prediction scheme uses 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 Xo (i,j) in Xo, diagonal predictor Xd (i,j) are described as follows and one of them is chosen as a predictor for Xo (i, j).

$$Xd\ (i,j) = \text{round}\left[\frac{xe(i+1,j-1)+xe(i-1,j-1)+xe(i-1,j+1)+xe(i+1,j+1)}{2}\right] \quad (3)$$

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. Xo(2) Odd subimage is compressed through which even subimage Xo(2) is generated. These compressed 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. Algorithm 1 and Algorithm 2 shows the implementation strategy for the modified hierarchical prediction method.

Algorithm: 1

if ($|x_o$ (i, j) - x_h (i, j)$|$ + T1 < $|x_o$ (i, j) - x_v (i, j)$|$) &&

($|x_o$ (i, j) - x_h (i, j)$|$ + T2 < $|x_o$ (i, j) - x_d (i, j)$|$)

then

dir (i, j) ←H

else if ($|x_o$ (i, j) - x_v (i, j)$|$ + T1 < $|x_o$ (i, j) - x_h (i, j)$|$) &&

($|x_o$ (i, j) - x_v (i, j)$|$ + T2 < $|x_o$ (i, j) - x_d (i, j)$|$)

then

dir(i,j) ←V

else

dir(i,j) ←D

end if

Algorithm: 2

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

x_o (i,j) ← x_h (i,j)

else if dir(i,j) = V then

x_o (i,j) ← x_v (i,j)

else

x_o(i,j) ← x_d(i,j)

end if

else if dir(i,j) = V or dir(i+1,j) = V

Calculate 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 or dir (i+1, j+1) = D then

Compute dir(i,j) by algorithm 1

end if

A. Proposed Modified Hierarchical Prediction and Context Adaptive (MHPCA) Coding

For the compression of images, the RGB image is first transformed to YCuCv by reversible color transform method. Luminance channel Y is also encoded by Modified Hierarchical decomposition scheme. The chrominance channels Cu and Cv resulting from the RCT usually have different statistics from Y, and also different from the original color planes R, G, and B. For encoding chrominance channels (Cu and Cv) modified hierarchical prediction method is used.

Modified Hierarchical Prediction and context adaptive coding (MHPCA) uses the vertical, horizontal, diagonal (left up, left down and right up, right down pixels) pixels are predicted to progress with the compression process. Pixels in an input image the luminance and the chrominance image X is separated into two subimage: an even subimage Xe and an odd subimage Xo. Then, Xe is encoded first and is used to predict the pixels in Xo. For the compression of Xo pixels using Xe, directional prediction is employed to avoid large prediction errors near the edge.

IV. PERFORMANCE PARAMETERS

Performance parameters are inevitable while trying to compress the images while still maintain the sharpness of the image using different technologies. Below provided are some of the parameters required to be considered in order to measure the efficiency of any compression algorithm:

- A bit per pixel value of an image is the ratio between Data size of image in bits and Number of pixels.

$$\text{Bits per pixel (BPP)} = \frac{Datasize\ of\ Image(in\ bits)}{No.\ of\ Pixels}$$

- Image compression ratio is defined as the ratio between the compressed image and original Image.

$$\text{Compression Ratio (\%)}\ \ CR = 100 - \left[\frac{Compressed\ image}{Original\ image} \times 100\right]$$

- Peak signal to noise ratio is used for the quality measurement between the original and a compressed image.

$$\text{Peak Signal to Noise Ratio: PSNR} = 10\log_{10}\frac{R^2}{MSE}$$

Where, R is the maximum fluctuation in the input image data type. For example, if the input image has a double-precision floating-point data type, then R is 1. If it has an 8-bit unsigned integer data type, R would be 255.

$$\text{MSE} = \frac{\sum_{M,N}[L(m,n)-K(m,n)]^2}{M*N}$$

In this equation L(m,n) and K(m,n) are image sizes of original and compressed images respectively. M and N are the number of rows and columns of an input image respectively.

V. RESULTS AND DISCUSSION

In this section the performance parameters are compared among existing and proposed scenarios by using efficient methodologies. The performance parameters are considered as Bits Per Pixel (BPP), Compression Ratio (CR) and Peak Signal to Noise Ratio (PSNR).

A. Comparison among (HPCA) Coding and Proposed (HPCA) coding scheme

1. Bits per pixel

Images	H.P.C.A	Proposed H.P.C.A
Lena	19.6115	19.5522
Mandril	6.0871	5.5049
Peppers	3.8725	3.4393
Barbara	16.3186	15.8398
Vegetables	12.2026	12.0779
Flower	2.1032	2.0482
Land	3.4404	3.0680
Terrain	2.7120	2.3855
Garden	2.5517	2.4461

Images	H.P.C.A	Proposed H.P.C.A
Walkway	1.9238	1.8521
Pink	2.0350	1.9814
Seasaw	1.8823	1.8040
Cars	1.7993	1.7539
Palace	1.9437	1.8759
Residency	2.1961	2.1308
Circle	1.9770	1.8808
Field	2.4716	2.3171
Rv	2.3833	2.2520

2. *Compression Ratio*

Images	H.P.C.A	Proposed H.P.C.A
Lena	18.3920	18.6386
Mandril	19.5311	27.2269
Peppers	12.3209	22.1296
Barbara	12.7572	15.3168
Vegetables	11.8577	12.7586
Flower	18.6844	20.8101
Land	22.1366	30.5658
Terrain	30.7629	39.0974
Garden	39.7821	42.2723

Images	H.P.C.A	Proposed H.P.C.A
Walkway	9.3008	12.6810
Pink	28.5661	30.4488
Seasaw	35.8488	38.5184
Cars	3.0740	5.5196
Palace	23.4968	26.1654
Residency	4.1669	7.0142
Circle	51.0837	53.4633
Field	38.7916	42.6178
Rv	46.1166	49.0857

3. *Peak Signal to Noise Ratio (PSNR*)

Images	H.P.C.A	Proposed H.P.C.A
Lena	39.7816	37.6004
Mandril	30.7757	29.9133
Peppers	33.9521	32.6834
Barbara	50.2129	37.9699
Vegetables	42.8459	40.6835
Flower	46.7223	43.2803
Land	44.2612	38.8278
Terrain	43.6254	39.9099
Garden	43.9123	40.0041

Images	H.P.C.A	Proposed H.P.C.A
Walkway	49.3084	43.1698
Pink	46.2816	43.7451
Seasaw	46.9947	43.4563
Cars	49.1599	44.5421
Palace	47.6703	41.9929
Residency	48.2862	40.4408
Circle	44.0947	40.7306
Field	43.2058	39.1200
Rv	43.8406	39.1512

B. Comparison among (MHPCA) Coding and Proposed (MHPCA) coding scheme

1. *Bits per pixel*

Images	M.H.P.C.A	Proposed M.H.P.C.A
Lena	19.4273	18.8383
Mandril	6.0543	5.6096
Peppers	3.8385	3.5644
Barbara	16.2797	15.7797
Vegetables	12.0867	11.8205
Flower	2.1015	2.0746
Land	3.4386	3.1859
Terrain	2.7102	2.3724
Garden	2.5491	2.4721

Images	M.H.P.C.A	Proposed M.H.P.C.A
Walkway	1.9229	1.8590
Pink	2.0330	2.0147
Seasaw	1.8815	1.7516
Cars	1.7984	1.7763
Palace	1.9428	1.8844
Residency	2.1950	2.1892
Circle	1.9764	1.8012
Field	2.4712	2.2720
Rv	2.3824	2.2618

2. *Compression Ratio*

Images	M.H.P.C.A	Proposed M.H.P.C.A
Lena	19.1583	21.6094
Mandril	19.9648	25.8431
Peppers	13.0927	19.2967
Barbara	12.9651	15.6379
Vegetables	12.6948	14.6173
Flower	18.7469	19.7904
Land	22.1783	27.8974
Terrain	30.8093	39.4329
Garden	39.8433	41.6610

Images	M.H.P.C.A	Proposed M.H.P.C.A
Walkway	9.3393	12.4998
Pink	28.6367	29.2799
Seasaw	35.8788	40.3028
Cars	3.1196	4.3128
Palace	23.5305	25.8305
Residency	4.2120	4.4680
Circle	51.0976	55.4345
Field	38.8006	43.7345
Rv	46.1363	48.8632

3. Peak Signal to Noise Ratio (PSNR)

Images	M.H.P.C.A	Proposed M.H.P.C.A
Lena	39.0406	36.6613
Mandril	30.7773	29.9750
Peppers	33.9562	32.6864
Barbara	48.1822	36.9835
Vegetables	41.6426	39.1298
Flower	46.5922	41.4843
Land	44.2396	37.2425
Terrain	43.6151	38.8229
Garden	43.8873	38.8556

Images	M.H.P.C.A	Proposed M.H.P.C.A
Walkway	49.3873	41.4109
Pink	46.0981	41.8048
Seasaw	46.9468	41.8976
Cars	49.3520	42.9469
Palace	47.5637	40.4935
Residency	48.4518	39.5036
Circle	44.1093	40.1029
Field	43.2570	38.4651
Rv	43.7913	38.4132

VI. CONCLUSION

Hierarchical Prediction algorithms, much discussed in previous literature, forms one component of an existing image compression technologies. Another essential component that has received little or no attention is implementing the combination of different methods evolved under Hierarchical Prediction. From the experimental results it is concluded that proposed methods yields less bits per pixel value and significantly increase the compression ratio. But the PSNR value is not increased by using the proposed methods. Images are taken here are some standard images and rest are the self captured images. The requirement for this second component becomes evident once we recognize how effectively the images can be compressed while still maintaining the sharpness with reasonable amount of computing time and resources. Though there are different variants of Hierarchical Prediction already been implemented with considerably good quality image compression, the improvement is still possible. Additionally the focus should also be given to the way the algorithms are implemented – taking into account the time it takes to execute and the computing resources it utilizes along with efficient image compression.

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