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Color Image Compression using Linear Prediction Coding

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Abstract: Data compression is a process of reducing the data size to minimize the storage size and the data transmission time, will decompression means recovering the original data without losing any piece of information. In this research paper we will introduce an efficient method of data compression-decompression, this method will based on using FIR filter coefficients and linear prediction coding, the method will be tested and implemented to show how this method will increase the compression ratio and how to speed up the process of compression-decompression by comparing the obtained experimental results with the results of other existing methods.
Keywords: Color image, compression, decompression, PLC, FIRF, CT, DT, coefficients, compression ratio.

1- Introduction

Digital color image [1-6] is one of the most important data type used in the internet environment, it is usually has a high resolution and a big size and it is represented by a 3D matrix [7-15] as shown in figure 1, the first dimension is reserved for the red color, the second for the green, while the third one is reserved for the blue color.

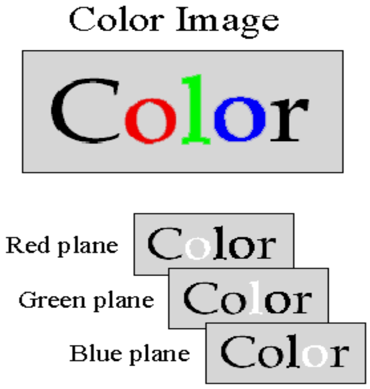

Figure 1: Color image components

Color image consists of a set of pixels as shown in figure 2, each pixel acquire 24 bits (3 bytes), each byte is used to handle the color value, giving it a range from 0 to 255, mixing the values gives the true color of the pixel [16-27]as shown in figure 3.

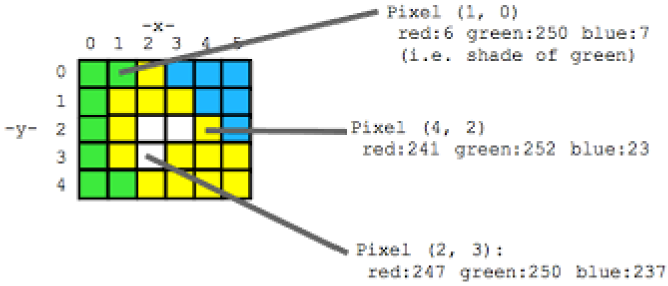

Figure 2: Color pixel

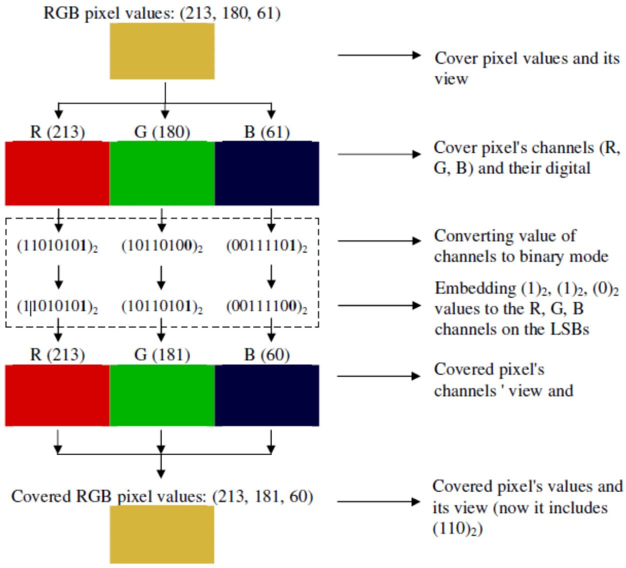

Figure 3: Mixing the colors to get the pixel true color

Color images have huge sizes [1], [2], [3], so they require more time for data transmission and more memory space for storing, so reducing the image size is an important task.

Compression operation is used to reduce the image size by a factor called compressing ratio (CR), which is equal the original image size divided by the compressed file size (see figure 4), and for effective method of compression this factor must be greater than 1, and the higher its value, the more effective the method of compression

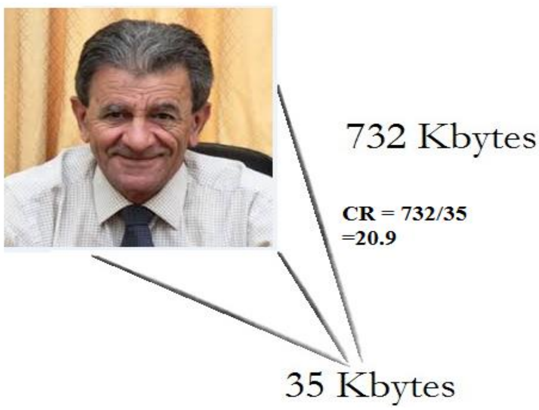

Figure 4: Compression ratio

Compression reduces the transmission time by reducing the image size, for example: residential internet connections deliver data at speeds ranging 56 Kbps via conventional phone lines to more than 12 Mbps for broadband, the time required to transmit a small 128x128x24 bit full color image over this range of speeds is from 7 to 0.03 seconds, if CR=20, then range will be reduced to 0.35 to 0.0015 seconds [28], [29].
Image compression plays an important role in other areas, including tele-video conferencing, remote sensing, storage, and transmission of binary, gray scale, and color images [30], [31].
The importance of compression operation forces us to seek an effective method of data compression; efficient method of data compression will be characterized by the following features:

- Compression time minimization.
- Decompression time minimization.
- CR maximization.
- Data lose minimization; the decrypted data must equal or very closed to the original data.

Many methods are now used for data compression-decompression such as LZW, Huffman and DCT methods; table 1 summarizes the features of these methods [28-33]:

Table 1: LZW and Huffman CR [28]

Image size	LZW CR	Huffman CR	LZW enhancement(increasing)
150696(jpg)	**1.1999**	**1.0741**	1.1171
150696	**1.2305**	**1.0089**	1.2196
150801	**1.4213**	**1.0851**	1.3098
150975	**1.3257**	**1.0783**	1.2294
150975	**1.3011**	**1.0451**	1.2450
151704	**1.2599**	**1.0260**	1.2280
720000	**1.3760**	**1.0768**	1.2779
949500	**1.9435**	**1.2278**	1.5829
1008342	**1.3245**	**1.0280**	1.2884
2101248	**1.7381**	**1.3081**	1.3287
50303(png)	7.6752	**3.6428**	2.1070

2- Finite Impulse Response Filter

The term finite impulse response (FIR) [34], [35] arises because the filter output is computed as a weighted, finite term sum, of past, present, and perhaps future values of the filter input, the filter output can be executed as a convolution of the input signal and FIR coefficients as shown in the following formulas:

$$y(n) = \sum_{k=0}^{M-1} b_k x(n-k)$$

For a 4 order FIR the output will be computed as follows:

$$y(n) = b_0 x(n) + b_1 x(n-1) + b_2 x(n-2) + b_3 x(n-3) + b_4 x(n-4)$$

Figure 5 shows the block diagram of 5 order FIR filter, while figure 6 shows how to calculate each sample of the output signal.

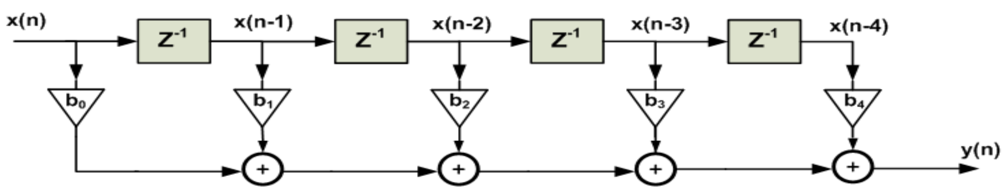

Figure 5: 4 order FIR filter.

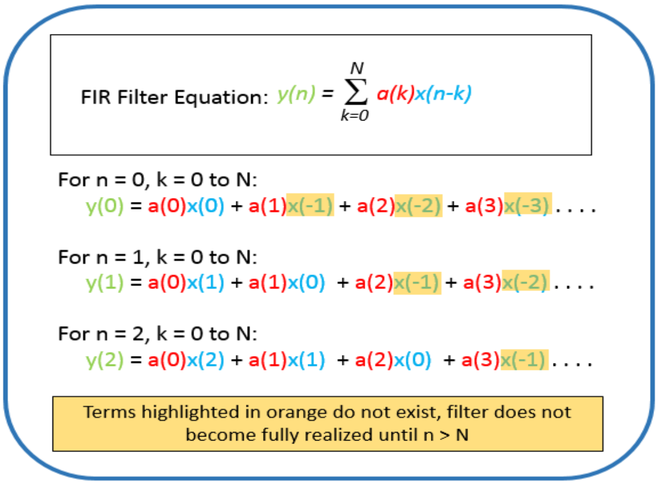

Figure 6: Samples calculation

Knowing FIR filter coefficients we can reconstruct the original signal by applying convolution, to retrieve FIR filter coefficients we can use linear prediction coding (LPC) and the process of data reconstruction is shown in figure 7:

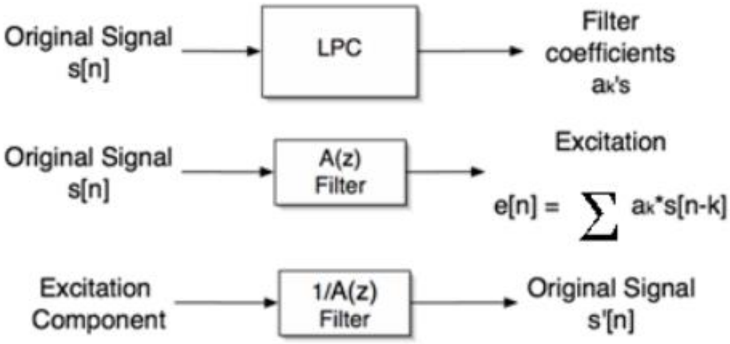

Figure 7: Signal reconstruction

To use LPC for compression-decompression we can apply the following steps:

- Get the original color image.
- Reshape image 3D matrix to 1 row array.
- Get the image size.
- Select FIR order (N).
- Initiate a compressed file
- Apply LPC matlab function to retrieve FIR coefficients.
- Store number of samples, starting pixel values (N) and FIR coefficients (N) in the compressed file (array) as shown in figure 8.
- Save the compressed file.

Number of samples 1 feild	**Starting pixels values n feilds**	**FIR coefficients n feilds**

Figure 8: Compressed file

The decompression process will be implemented applying the following steps:

- Get the compressed file.
- Separate the compressed file fields.
- Apply convolution using the field's values.

Figures 8 and 9 show an original image and the reconstructed one applying the previous mentioned steps.

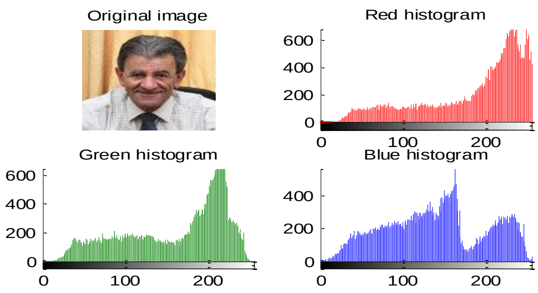

Figure 8: Original image

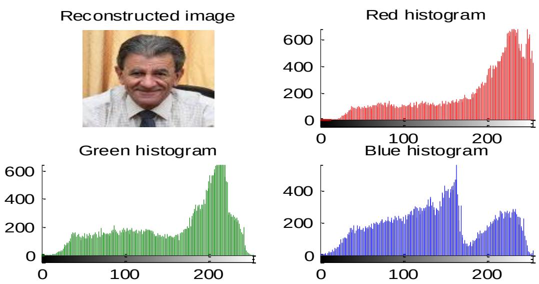

Figure 9: Reconstructed image

3- Implementation and Experimental Results

The proposed method was implemented using various images, the following experiments were executed:

Experiment 1: Using small images with number of FIR coefficients = 3.

Table 2 shows the contents of the compressed file for each compressed image

Table 2: Compressed files contents

image	Resolution(pixel)	Size(byte)	Compressed file						
			size	**Initial values**			**Coefficients**		
1	25992	77976	**77976**	**252**	**246**	**244**	**-0.8445**	**0.0910**	**-0.2390**
2	40755	122265	**122265**	**52**	**52**	**53**	**-0.7872**	**0.1032**	**-0.3031**
3	50283	150849	**150849**	**235**	**234**	**231**	**-0.8628**	**0.0386**	**-0.1470**
4	50325	150975	**150975**	**12**	**44**	**39**	**-1.0778**	**0.1568**	**-0.0755**
5	50400	151200	**151200**	**8**	**0**	**10**	**-0.8073**	**0.0122**	**-0.1756**
6	50451	151353	**151353**	**225**	**225**	**225**	**-1.2907**	**0.4324**	**-0.1385**
7	50625	151875	**151875**	**157**	**157**	**158**	**-0.7117**	**-0.1314**	**-0.1232**
8	172800	518400	**518400**	**0**	**0**	**0**	**-1.2297**	**0.4361**	**-0.1901**
9	264864	794592	**794592**	**127**	**103**	**80**	**-1.1852**	**0.4917**	**-0.2809**

The compressed file size depends on the selected order of FIR filter.

Experiment 2: Compression ratio of compression small image using various FIR order

Here we select the 6th image, and then we apply compression-decompression using various FIR orders.

Table 3 shows the results of this experiment:

Table 3: Varying FIR order

Number of coefficients	Resolution	size	Compressed file size	Compression time	Decompression time	Compression ratio	Correlation
3	50451	77976	49	0.103000	0.104000	3088.8	0.9804
4	50451	77976	72	0.107000	0.105000	2102.1	0.9808
8	50451	77976	136	0.118000	0.125000	1112.9	0.9810
12	50451	77976	200	0.123000	0.127000	756.8	0.9811
20	50451	77976	328	0.129000	0.132000	461.4	0.9812
50	50451	77976	808	0.131000	0.139000	187.3	0.9813
64	50451	77976	1032	0.132000	0.139300	146.7	0.9813
80	50451	77976	1288	0.137000	0.139500	117.5	0.9813
100	50451	77976	1608	0.139000	0.139700	94.1	0.9814

Experiment 3: Compression ratio of compression small images using 20 order FIR
Here we select 9 small images, and then we apply compression-decompression using various FIR orders.
Table 4 shows the results of this experiment:

Table 4: Compression small images with FIR order=20

image	Resolution	size	Compressed file size	Compression time	Decompression time	Compression ratio	Correlation
1	25992	77976	328	0.064000	0.061000	237.7	0.8946
2	40755	122265	328	0.075000	0.067000	372.8	0.9329
3	50283	150849	328	0.112000	0.118000	459.9	0.9412
4	50325	150975	328	0.121000	0.124000	460.3	0.9867
5	50400	151200	328	0.123000	0.126000	461.0	0.9707
6	50451	151353	328	0.129000	0.132000	461.4	0.9812
7	50625	151875	328	0.131000	0.137000	463	0.9830
8	172800	518400	328	0.141000	0.147000	1580.5	0.9554
9	264864	794592	328	0.152000	0.152000	2422.5	0.9882
Average		252165	328	**0.1164**	**0.1182**	**768.7889**	**0.9593**

Experiment 4: Compression ratio of compression big images using 100 order FIR
Here we select 8 big images, and then we apply compression-decompression using various FIR orders.
Table 5 shows the results of this experiment:

Table 5: Compression big images with FIR order=100

image	Resolution(pixel)	Size(byte)	Compressed file size	Compression time	Decompression time	Compression ratio	Correlation
1	440592	1321776	1608	0.804000	0.967000	822	0.9677
2	630000	1890000	1608	0.961000	1.078000	1175.4	0.9861
3	833536	2500608	1608	3.070000	2.580000	1555.1	0.9538
4	1272384	3817152	1608	2.476000	2.580000	2373.9	0.9802
5	1306200	3918600	1608	2.651000	2.831000	2436.9	0.9840
6	1442070	4326210	1608	2.951000	2.978000	2690.4	0.9794
7	1713600	5140800	1608	3.151000	3.297000	3197	0.9870
8	2073600	6220800	1608	5.653000	5.760000	3868.7	0.9981
Average		3642000	1608	**2.7146**	**2.7589**	**2264.9**	**0.9795**

From the obtained experimental results we can see the following facts:
Comparing with other methods the proposed method minimizes compression-decompression times, increases compression ratio, minimizing the error between the original file and the decompressed one by giving a high value of correlation between them.

Conclusion
A method based on FIR filter coefficients and linear prediction coding was presented, tested and implemented. It was shown that the proposed method is very efficient by decreasing both compression and decompression times, rapidly increases the compression ration.
The proposed method was accurate by achieving the similarity between the original and decompressed file by increasing the correlation between them when we select a high order FIR filter.

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