Predictive Lossless Image Compression (PLIC) Algorithm and its Coding Analysis

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Abstract

The PLIC algorithm [1] is a predictive image compression method that involves a tight region of support composed of six pixels plus the pixel that will be compressed. In this paper, we present an analysis of two types of coding schemes that can be used for the residuals that are involved in the PLIC method. The first type of coding explored is the Huffman Code, which is a variable-length type of coding in which the most frequent symbol is assigned the shortest code. The second type of coding is a sub-optimal 5-bit coding of the residuals that fall within an interval of [-31 to 30]. The rest of the residuals are coded using 13 bits. Results using several images are presented. The sub-optimal was found to be pretty close to the optimal in certain images processed in this work.

1. INTRODUCTION

The past two decades have witnessed vigorous research activities in the area of image compression. As a result, a multitude of different image coding techniques have emerged. The compression techniques can be broadly categorized into two classes; namely, lossy and lossless[2],[3]. The PLIC[1] algorithm is a lossless type of compression scheme and is used in this work. The PLIC Algorithm is based on the work done by M. Das[4]. A lossless scheme typically achieves a compression ratio of the order of two, but will allow exact recovery of the original image from the compressed version. The applications of this type of compression scheme is endless, for example, in medical applications the lossless scheme is ideally suited, as any loss of information may be unacceptable to the radiologist.

2. PLIC ALGORITHM OVERVIEW

2.1 Encoder

In the PLIC scheme, the pixels, Y_i ,are processed in a raster-scan fashion, meaning pixel by pixel, row by row. The procedure of encoding can be illustrated in a multi-step strategy. The prediction model chosen for the approximation of a pixel to be coded is based on a spatially causal region of the image as shown in Figure 1.

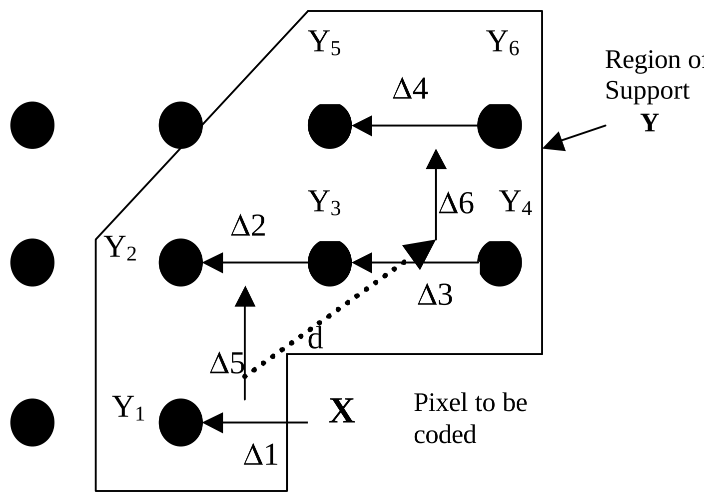

Figure 1: Region of Support for the PLIC

Correlation coefficients, a_i , are calculated between two parameters (W_i , W_{i+1}), defined by eq. 1.

$$a_i = \frac{W_i \bullet W_{i+1}}{W_j^2} \quad \forall \text{ i} = 1,2,\ldots,7 \qquad (1)$$

where j = 1 or j = i + 1, such that $|a_i| < 1$ and $W_i = Y_i$ for i = 1,…,4, and $W_i = \Delta i$ for i = 5,6,7. Also, the difference, Äi, between two adjacent pixels, is calculated using eq. 2.

$$\Delta i = Y_i - a_i \bullet Y_{i+1} \qquad (2)$$

The encoding operation consists of five steps:

Step #1: Calculate, using eq. 1, the first four correlation coefficients, a_i for i = 1,2,3,4, for the pixels in the three rows in the region of support.
Step #2: Calculate, using eq. 2, the four differences, Δi, i = 1,2,3,4, between two adjacent pixels in the same row, using their corresponding correlation coefficients.
Step #3: Using the differences from step #2, the correlation coefficients, a_5 and a_6, are calculated by eq. 1.
Step #4: The differences $\Delta 5$ and $\Delta 6$ are calculated using the correlation coefficients obtained in the earlier step. a_7 is calculated using $\Delta 5$ and $\Delta 6$ by eq. 1.
Step #5: The last difference or residual, R, is calculated by eq. 3.

$$R = \Delta 5 - a_7 * \Delta 6 \qquad (3)$$

After the residuals for all the pixels are calculated, they are coded and transmitted. A more detailed discussion of the coding process is presented in the following section.

2.2 Decoder
At the decoder, the residuals are extracted from the received codes depending on the coding scheme that was used on the encoder. The same process that was used at the encoder are used at the decoder. Then the value of the original pixel can be obtained using eq. 4.

$$X = R + \begin{bmatrix} \mathbf{a}_1 & \mathbf{a}_5 & \mathbf{a}_7 \end{bmatrix} \begin{bmatrix} \mathbf{y}1 \\ \Delta 2 \\ \Delta 6 \end{bmatrix} \qquad (4).$$

3. CODING ANALYSIS

Two types of coding schemes were used: Sub-Optimal 5-bit coding, and Huffman coding. The coding schemes are presented in sections 3.1 & 3.2.

3.1 Sub-Optimal 5-bit Coding

After PLIC is applied, the majority of the residuals fall within a certain narrow interval. A typical histogram of the distribution of the residuals is shown in Figure 2. The Compression Ratio as a function of the number of bits assigned to a higher frequency residual is given by eq. 5.

$$CR = 8 / [b_n * h + (8+b_n)(1-h], \qquad (5)$$

where h is the occurrence of residual values within a certain interval of: $-(v+1)<R<v$ and $b_n = \log_2 (v+2) + 1$. The v is the positive limit of the narrow interval in Fig. 2.

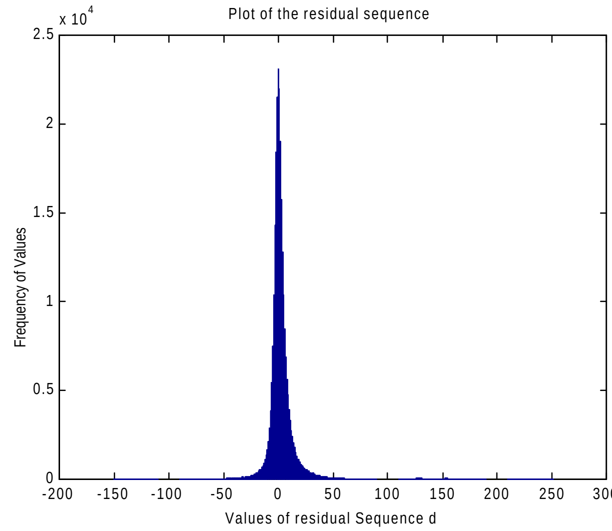

Figure 2: Histogram of the residual sequence for Lena image

Several images were encoded using the PLIC algorithm, and b_n was varied from 3 to 8 bits for each image. The value of h was obtained from the image residual histogram. The results showed that the highest compression took place at b_n =5 bits. These results are shown in Figure 3.

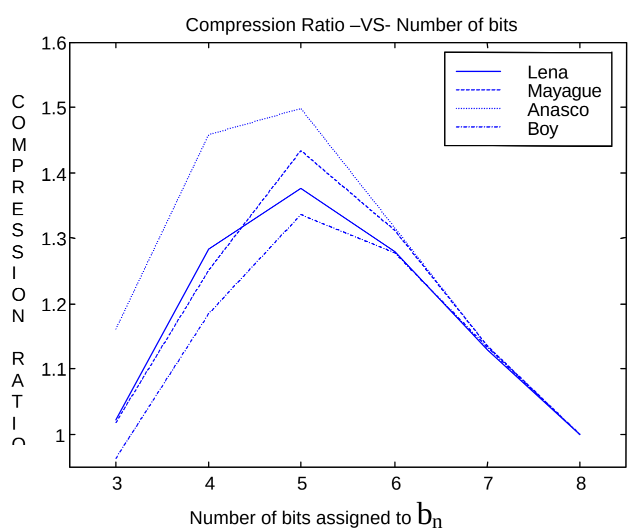

Figure 3: Results for different values of b_n

The values of the residuals that fall within the interval (-31,30) were coded using 5 bits and the rest of the other values were coded using 13 bits.

3.2 Huffman Coding

Figure 2 shows that a large percentage of the residuals is centered around 0. This means that these numbers are the most frequent ones in the sequence. To take advantage of this we use Huffman Coding. Huffman Coding is a variable-length coding in which the most frequent symbol is assigned the shortest code. In this case, the symbols are the values of the residual sequence.

4. RESULTS

The results of the number of bits per pixel used for the two coding schemes, for various images, are presented in Table 1.

Table#1: Coding results in bits per pixel

Image	Sub-optimal 5-bits	Huffman
Lena	5.2397	5.08
Mayaguez	5.096	4.91
Anasco	5.0735	4.44
Boy	5.2467	5.09
Baby	5.1379	3.99
Hanging Dollars	5.5315	4.43
New York	5.5539	4.48
Rose	5.1093	4.12
Mountains	5.2947	4.89
Parrot	5.2050	4.36
Girl	5.2249	5.1
Dad and Girl	5.1178	4.44
Hats	5.2453	4.53
Baby Girl	5.2267	4.88
Balloon	5.1742	4.21
Map	5.0968	5.09

As it can be seen, Huffman coding presents a more optimal approach for coding the residuals. For some images, the sub-optimal 5-bit scheme and the Huffman scheme produce near similar results. Figure 4 shows plots of several images that were compressed using the lossless PLIC algorithm.

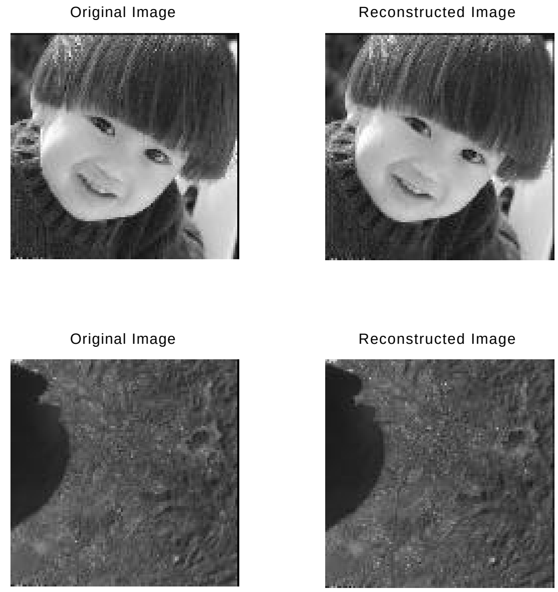

Figure 4: Original and Reconstructed Images

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