PERFORMANCE EVALUATION OFADVANCED LOSSLESS IMAGE COMPRESSION TECHNIQUES

M.Amarnath
M.E Scholar
Department of Computer Science & Engineering
Manonmaniam Sundaranar University
Tirunelveli-627012, India
amararjun2207@gmail.com

T.IlamParithi
Research Scholar
Department of Computer Science & Engineering
Manonmaniam Sundaranar University
Tirunelveli-627012, India
iparithy@gmail.com

Dr.R.Balasubramanian
Professor & Head
Department of Computer Science & Engineering
Manonmaniam Sundaranar University
Tirunelveli-627012, India
rbalus662002@yahoo.com

Abstract – In recent days, the usages of data in the form images are very high. These images require a large amount of space for storage, large transmission bandwidths and long transmission times. The only way to find the solution to this problem is Compression. Compression is used to reduce the space for storing an image. The main aim of this work is to analyse the performance of lossless compression techniques such as Lossless Predictive Coding (LPC), Lossless JPEG compression (LJPEG) and Context Adaptive Lossless Image Compression (CALIC) method. The performance metrics such as Compression Ratio (CR), Mean Square Error (MSE), Peak Signal-to-Noise Ratio (PSNR) and Bits Per Pixel (Bpp) are computed for the image compression techniques. From the evaluated result, CALIC is giving better performance in compression than other two compression techniques.

Keywords – image compression, LPC, CALIC and LJPEG, Prediction, De-prediction.

I. INTRODUCTION

Image Compression is the art of representing the information in a compact form rather than its original or uncompressed form. This is very useful when processing, storing or transferring a huge file, which needs lots of resources. If the algorithms used to encrypt works properly, there should be a significant difference between the original file and the compressed file. When compression is used in a data transmission application, speed is the primary goal. The main advantage is to compress the image by storing only the essential information needed to reconstruct the image. Compression is the process reducing the size of image for storing and transferring the image. Compression is done by removing the redundancy data present in the image. Basically there are three types of redundancies; they are Coding Redundancy, Interpixel Redundancy and Psycho visual Redundancy. Coding redundancy is used to represent less code symbols to represent each gray level. Interpixel redundancy results in correlations between pixels. Psycho visual redundancy occurs due to data ignored by human visual system.

Compression is mainly classified into two types, Lossy Compression and Lossless Compression. In Lossy compression, the original data is reconstruct with loss of some information. It is not possible to reconstruct the original data using the decoding process, and is called irreversible compression. The decompression process results an approximate reconstruction. In Lossless compression, it reconstructs the original data from the compressed data without any loss of data. Thus, the information does not change during the compression and decompression processes. These kinds of compression algorithms are called reversible compressions.The main aim of data compression is using less amount of data to represent the original data without affect the image quality. In order to evaluate the performance of image compression techniques, we must define some measures namely Compression ratio (CR), Bits Per Pixel (Bpp), Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) . The higher value of compression ratio produces the reduction in the quantity of data. The lower value of MSE and the larger value of PSNR give the better quality in the compressed image.

II. VARIOUS LOSSLESS IMAGE COMPRESSION TECHNIQUES

2.1 Lossless Predictive Coding

Lossless Predictive Coding (LPC) [15] was proposed by Seyum Kim and NamIk Cho, Predictive coding reduces the Interpixel redundancy as there will be much correlation between the pixels. This technique results in both Lossy and Lossless compression. In LPC it predict the next pixel value by using its previous pixels value but it will results in prediction error. The error will be a smaller value as it compared to the original value. The error will be then encoded using Huffman coding or Arithmetic coding and decoding is be done by using variable length decoder. The Lossless Predictive Coding model includes an encoder and a decoder.

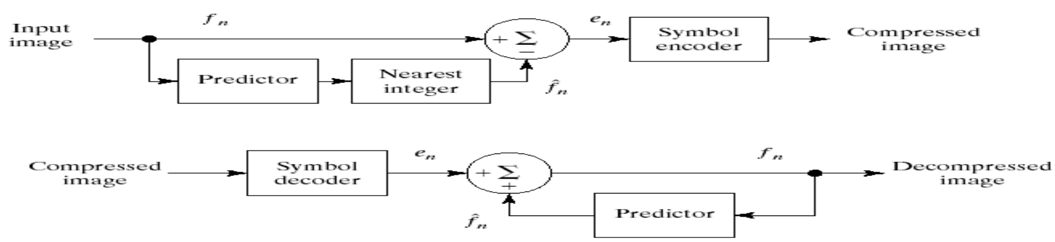

Figure2.1.Block diagram of LPC

The basic components of a predictive encoder are shown in Fig.2.1 are: Predictor, nearest integer block and Symbol encoder. First, each pixel of the input image, F(n) is loaded into the encoder one by one. The predictor produces the predicted value of the input pixel. The rounded value is denoted as Fˆn. The difference obtained is encoded by the symbol encoder. The output of the symbol gives the next element of the compressed data stream**.** The components of a predictive decoder are: Symbol decoder and De-predictor. The decoder performs the inverse operation of encoder. It receives the code words from the encoder output and reconstructs the prediction error, e (n).

- The Process

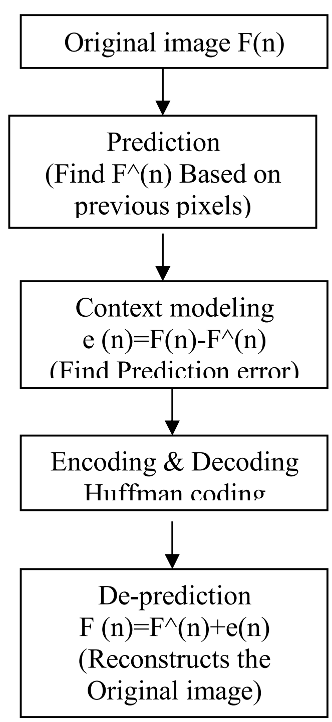

Figure 2.2.Process flow diagram of LPC

The diagram shown in Fig.2.2 indicates the flow diagram of image compression process of LPC. Firstly, LPC predicts the value of each pixel by using the values of its neighboring pixels. Every pixel is encoded with a prediction error rather than its original value. It is based on eliminating the redundancies of closely related pixels and coding new information in the pixel. The new information is the difference between the actual and predicted value of the pixel. The difference is coded by the symbol encoder and the output of the encoder gives the compressed data stream. The decoder performs the inverse operation of encoder and reconstructs the prediction error.

- Algorithm

STEP 1: The original image is defined as F(n).

STEP 2: Prediction is applied based on the neighboring pixels and output is F^(n)

STEP 3: The Prediction error is estimated as

$$e(n)=F(n)-\hat{F}(n) \quad \rightarrow \quad (1)$$

STEP 4: The compressed stream consists of first sample of prediction errors e(n) are encoded and then the decoded is done and get the prediction errors e(n) .

STEP 5: Prediction error is added to predictor value and get the original image F(n).

$$F(n)=e(n)+\hat{F}(n) \quad \rightarrow \quad (2)$$

2.2 Lossless JPEG

Lossless JPEG [16] (LJPEG) is actually a mode of operation of JPEG. In the lossless coding process employs a simple predictive coding model called DPCM. This is a model in which predictions of the sample values are estimated from the neighboring samples that are already coded in the image. Most predictors take the average of the samples immediately above and to the left of the target sample. DPCM encodes the differences between the predicted samples instead of encoding each sample independently. The differences from one sample to the next are usually close to zero.

The main steps of lossless operation mode are the predictor combines up to three neighboring samples at A, B, and C in order to produce a prediction of the sample value at the position labelled by X. The three neighboring samples must be already encoded samples. Once all the samples are predicted, the differences between the samples can be obtained and entropy-coded in a lossless fashion using Huffman coding.

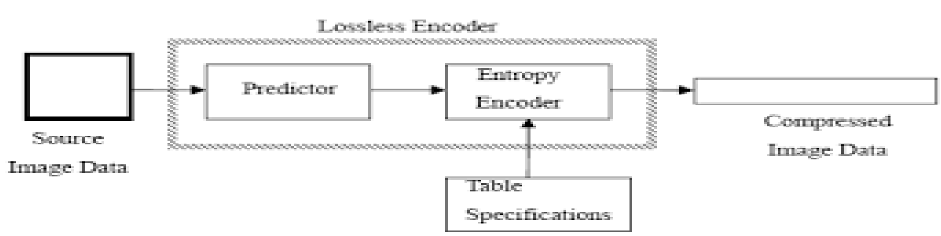

Figure 2.3 Block diagram of LJPEG

The LJPEG contains both an encoder and a decoder. The basic components of an encoder as shown in Fig 2.3 are: Predictor, Entropy encoder. Predictor predicts the pixel value based on neighboring pixels. The prediction error is obtained the difference of the predicted value and the original pixel. The components of a predictive decoder are: Symbol decoder and De-predictor. The original image is obtained by adding the prediction error and prediction value.

- The Process

The diagram shown in Fig.2.4 indicates the flow diagram of image compression process in LJPEG. Firstly, LJPEG predicts the value of each pixel by using the values of its neighboring pixels. Every pixel is encoded with a prediction error rather than its original value. It is based on eliminating the redundancies of closely related pixels and coding new information in the pixel. The new information is the difference between the actual and predicted value of the pixel. The difference is coded by the symbol encoder. The decoder performs the decoding process and reconstructs the original image by using predicted value.

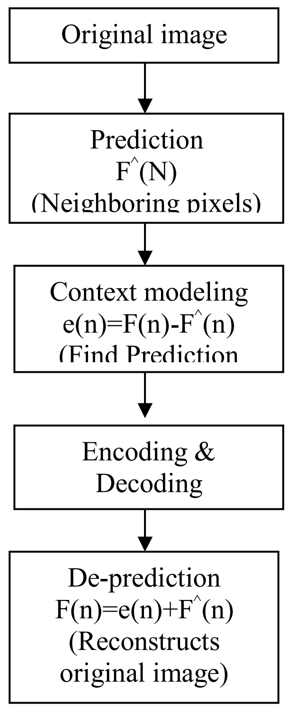

Figure 2.4.Process flow diagram of LJPEG

- Algorithm

STEP 1: Find prediction $F^{\wedge}(n)$ based on neighboring pixels.

STEP 2: Find prediction error e(n) is the difference between the original and the prediction value

$$e(n)=F(n)-F^{\wedge}(n) \longrightarrow \quad (3)$$

STEP 3: The prediction error e(n) is encoded & decoded by using Huffman coding.

STEP 4: The original image F(n) is obtained by adding the prediction error with prediction value.

$$F(n)=e(n)+F^{\wedge}(n) \longrightarrow \quad (4)$$

2.3 A Context Based Adaptive Lossless Image Compression

CALIC [2] was proposed to ISO/JPEG as a candidate algorithm for the next international standard for lossless compression of continuous-tone images. CALIC encodes and decodes images in raster scan order with a single pass through the image. The coding process uses prediction templates that involve only the previous two scan lines of coded pixels.

CALIC [15] operates in two modes: binary and continuous-tone modes. The binary mode is for the situation in which the current locality of the input image has no more than two distinct intensity values. The system selects one of the two modes on the fly during the coding process, depending on the context of the current pixel. In the binary mode, a Context-based adaptive ternary arithmetic coder is used to code three symbols. In the continuous mode, the system has four major integrated components: prediction, context selection and quantization, context modeling of prediction errors and entropy coding of prediction errors.

- The Process

The diagram shown in Fig.2.5 indicates the flow diagram of image compression process for CALIC. In continuous-tone mode, the neighbourhood of the pixel to be encoded has more than two distinct grey levels. In this mode, CALIC algorithm performs four operations: Initial Prediction, Context Selection, Context Modeling and Entropy Encoding.

The initial prediction is obtained for the pixel to be encoded using Gradient Adjusted Predictor (GAP)[8]. GAP is a simple non-linear predictor that utilizes gradients at pixel neighbourhood. The context selection is based on comparing the value of the initial prediction with the pixel neighbourhood's values. For each context, CALIC assumes that the GAP predictor is consistently repeating a similar prediction error.

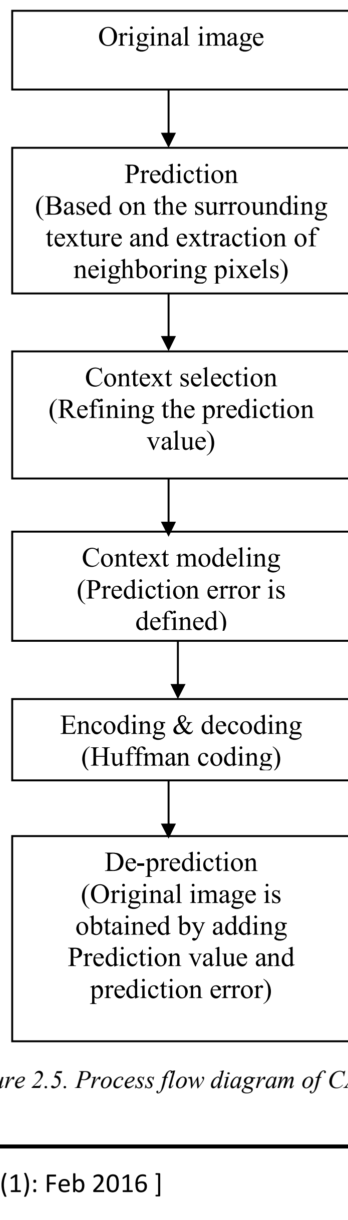

Figure 2.5. Process flow diagram of CALIC

- Algorithm

STEP 1: Prediction is done based in the surrounding texture and neighboring pixels.

STEP 2: Context Selection is obtained from the predicted value to refining the prediction value based on the horizontal and vertical distance of the predicted pixel.

STEP 3: In Context Modeling the prediction error is obtained the difference between the refined prediction value and original pixel value.

STEP 4: Encoding and Decoding is done by Huffman coding.

STEP 5: The original image is obtained by adding the prediction error with prediction value.

III RESULT AND DISCUSSION

In this, the image compression is done by using three techniques such as Lossless Predictive Coding, CALIC and Lossless JPEG method. Performance evaluation is based on CR, Bpp, MSE and PSNR for compressing the Image. If we get more compression ratio then CALIC method is consider as the best method.

3.1 Performance evaluation

- Performance Metrics

CR is used to find the ratio between the original image and the corresponding compressed image. Mathematically it is denoted as CR and it is calculated using the formula,

$$CR = \frac{Size\ of\ the\ compressed\ image}{Size\ of\ the\ original\ image} \longrightarrow (5)$$

Bpp is the acronym for Bits per Pixel. It is used calculate the number of bits required to represent an image. Usually binary image require 1 bit and gray scale image require 8 bits and a RGB colour image require 24 bits to represent an image. It can be calculated using the formula

$$L = 2^K \longrightarrow (6)$$

Where, L is the number of gray levels and k is the depth of the colour.

MSE is the cumulative squared error between the compressed image and the original image. The Mathematical formula for MSE is

$$MSE = \frac{1}{a*b}\sum_{a=1}^{a}\sum_{b=1}^{b}(m_{ij} - n_{ij})^2 \longrightarrow (7)$$

Where a × b is the size of the image, m_{ij} is the pixel value at the position (i, j) in the uncompressed image and n_{ij} is the pixel value of the compressed image at the same position.

PSNR is used to find the ratio between the maximum possible pixel value of an image and of corrupting noise that affects the fidelity criteria of an image. It is generally expressed in terms of logarithmic form. It will measure the quality of compressed image. This technique is mathematically very simple to trace and calculate.

$$PSNR = 20.\log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \longrightarrow (8)$$

Where MAX_I represents the maximum value of the image (i.e.) if we are using a grey scale image then the maximum value of it is 255, and MSE is calculated using above equation(7).

- Results evaluation

Table 1, shows the performance metrics such as Compression ratio, Bpp, Mean Square Error, Peak Signal to Noise Ratio and for compressed image are evaluated for the three lossless compression techniques such as Lossless Predictive Coding, CALIC and Lossless JPEG.

Image No.	LOSSLESS PREDICTIVE CODING				CALIC				LOSSLESS JPEG			
	CR	Bpp	MSE	PSNR	CR	Bpp	MSE	PSNR	CR	BpP	MSE	PSNR
1	5.9	1.345	0.987	47.8	7.2	1.099	0.004	69.7	4.1	1.987	0.012	72.1
2	8.5	0.964	0.923	47.1	9.5	0.854	0.009	71.0	7.8	1.045	0.015	72.5
3	0.9	8.364	0.956	47.8	1.3	5.956	0.007	73.7	0.5	13.312	0.031	72.8
4	10	0.789	0.948	47.2	11	0.621	0.006	70.1	7.0	1.124	0.024	72.2
5	2.7	2.946	1.065	48.0	3.2	2.419	0.004	71.8	2.1	3.776	0.022	72.2

Table 1. Compression ratio, Mean Square Error, Peak Signal to Noise Ratio and Bpp for compressed image

From this table, we infer that the CALIC method has MSE values are less for different images as compared with other two techniques, the PSNR values are good for different images and this method providing better compression compared to other techniques.

The performance evaluation for Lossless Predictive Coding is calculated with the help of graph.

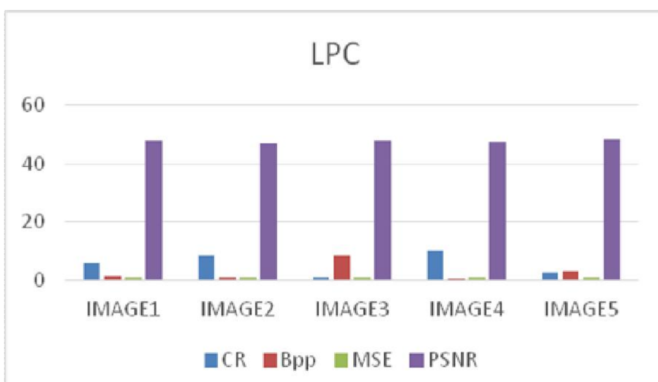

Figure3.1. Performance evaluation for LPC

For Lossless JPEG,

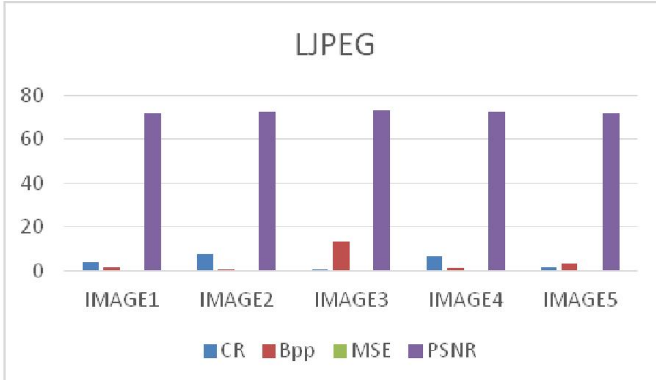

Figure 3.2. Performance evaluation for LJPEG

For CALIC,

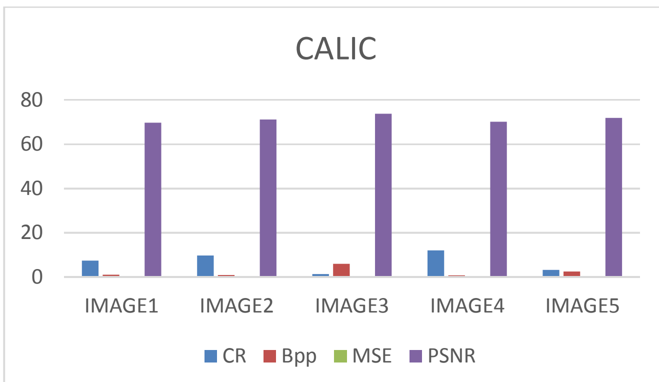

Figure 3.3. Performance evaluation for CALIC

Compression ratio for CALIC is better than other two techniques. CALIC obtained least error than other two techniques. Peak Signal Noise Ratio is higher for CALIC than other two techniques. Bpp is less compared to the other two techniques.

IV CONCLUSION

The performances of three compression techniques are evaluated. The results are verified for five general images by using four parameters (CR, Bpp, MSE and PSNR).. In LPC, the MSE values are high as compared with CALIC, the PSNR values are good for providing better quality and this method providing better compression ratio as compared with LJPEG method. In LJPEG, the MSE values are high as compared with CALIC , the PSNR values are high as compared with CALIC and this compression method providing less compression ratio as compared to other two methods. In CALIC method, the MSE values are less for different images as compared with other two techniques, the PSNR values are good and this method providing better compression compared to other techniques. Therefore from the overall results, the performance of CALIC method is best as compared to other two methods.

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