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Research Article

A Modified Image Template for FELICS Algorithm for Lossless Image Compression

Akshay G. Bhosale[Ȧ*] and Pravin S. Bidkar[Ȧ]

[Ȧ]Department of Electronics & Telecommunication, Sanjay Ghodawat Group of Institutions, Atigre, Tal. Hatkanagale, Kolhapur, Maharashtra, India

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Abstract

In this paper, a lossless image compression technique using FELICS algorithm is used for compressing the image. In this technique the pixels of image are coded using adjusted binary coding and Golomb-Rice coding. The coding of the pixel depends upon the position of the pixel in the image. The original image template in the FELICS algorithm has four different cases for position of pixel, but in this modified image template for FELICS algorithm we have proposed five cases. The quality of compressed images is compared by using various image quality parameters. After using this modified image template, we get slightly better compression ratio and reduced bit rate, this is achieved without affecting the other image quality parameters.

Keywords: *Adjusted binary coding, Compression ratio, FELICS algorithm, Golomb-Rice coding, Lossless compression, Image quality parameters.*

1. Introduction

Due to great innovation in display and information technology, the data storage capacity for storage of information has increased drastically. Now-a-days the high quality cameras produce high quality images. These high quality images require large amount of storage space. For such scenario, the data compression technique is applied to offer acceptable solution. Image compression is of two types, lossy and lossless compression. For lossy compression technique, many standards have been developed such as JPEG and JPEG 2000 for still images. In the lossy image compression technique, the reconstructed image is not exactly same as the original image. The lossless image compression can remove redundant information and guarantee that the reconstructed image is without any loss to original image. Different image compression techniques are suggested by the researchers, but the technique with high data compression with low loss is always preferred. The FELICS algorithm (P. G. Howard, *et al*, 1993) used in this system comes in the category of prediction based algorithms. Prediction-based algorithms apply prediction technique to generate the residual, and utilize the entropy coding tool to encode it.

In this paper, the proposed image template can provide slightly better compression ratio. The image template is used for generating the codewords for each pixel of the image. Here five different cases are proposed according to position of the pixel in the image which is to be encoded. The rest of this paper is organized as follows. The Section 2, presents VLSI-oriented FELICS algorithm. The proposed image template for FELICS algorithm is discussed in Section 3. Experiment results and discussions are described in Section 4. Finally, the conclusions are given.

*Corresponding author: **Akshay G. Bhosale**

2. VLSI-oriented FELICS algorithm

In this algorithm raster-scan order is used, and a pixel's two nearest neighbours are used to directly obtain an approximate probability distribution for its intensity, thus combining the prediction and error modelling steps.

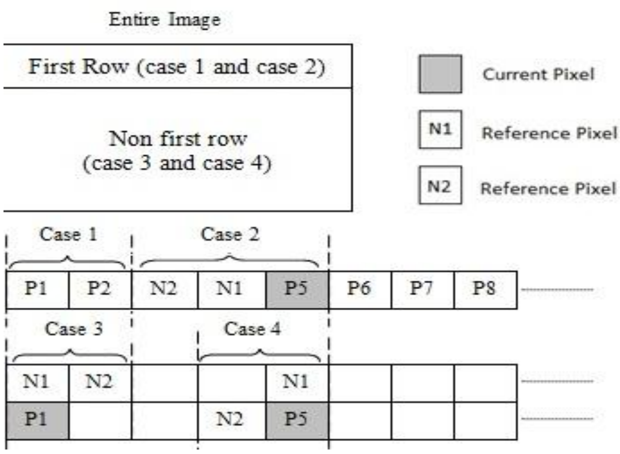


Fig.1 Illustration of prediction template in FELICS

FELICS utilizes two reference pixels around current pixel to yield the prediction template, and it can be divided into four cases. In case 1, since surrounding reference pixels are not available for the first two pixels, P1 and P2, both current pixels are directly packed into bit stream with original pixel intensity. For case 2, successive pixels, N1 and N2, are regarded as reference pixels for current pixel P5. For non-first row, cases 3 and 4, have different reference pixels. For case 3, the current pixel is to the left edge of image. For such a pixel, the reference pixels are the immediate top pixel and immediate top right pixel. For case 4, the current pixel is present anywhere in image other than first row or the left edge of the image. For such a pixel, the reference pixels are the immediate left pixel and immediate top pixel. The reference pixels are denoted as N1 and N2. Between N1 and N2, the smaller reference pixel is represented as L, and the other one is H. As in Fig.3, the intensity distribution model is exploited to predict the correlation between current pixel and reference pixels. In this model, the intensity that occurs between L and H is with almost uniform distribution, and regarded as *in-range*. The intensity higher than H value or smaller than L value is considered as *above range* and *below range*, respectively. For *in-range*, the adjusted binary code is adopted, and Golomb–Rice code is for both *above range* and *below range* (Tsung-Han Tsai, *et al*, 2010).

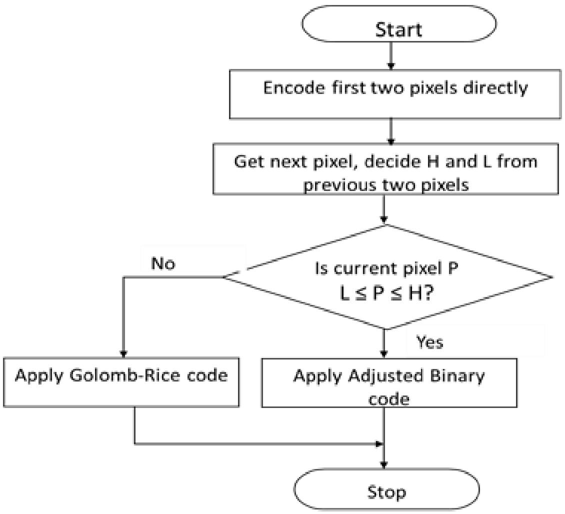


Fig.2 Flowchart for the FELICS Algorithm

2.1 Adjusted Binary Code

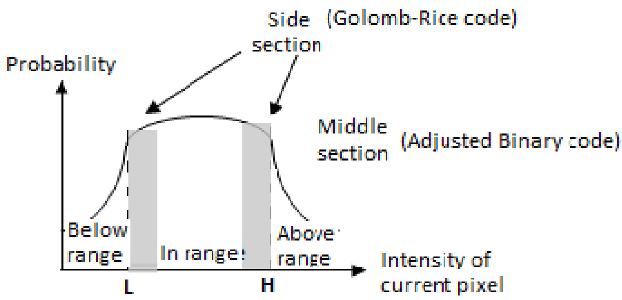


Fig.3 Probability distribution model in FELICS

Fig. 3 shows that the adjusted binary code is adopted in in-range, where the intensity of current pixel is between H and L. For in-range, the probability distribution is slightly higher in the middle section and lower in both side sections. Therefore, the shorter codeword is assigned to the middle section, and longer one is assigned to both side sections. To describe the coding flow of adjusted binary code, the coding parameters should be first computed as follows:

$$delta = H - L \quad (1)$$

$$range = delta + 1 \quad (2)$$

$$upper\_bound = \ ceil\log_2(range) \quad (3)$$

$$lower\_bound = floor\ \log_2(range) \quad (4)$$

$$threshold = \ 2^{upper\_bound} - range \quad (5)$$

$$shift\_number = \frac{(range - threshold)}{2} \quad (6)$$

The adjusted binary code takes the sample of P–L to be encoded, and range indicates that the number of possible samples should be encoded for a given delta. The upper_bound and lower_bound denote the maximum and minimum number of bits to represent the codeword for each sample, respectively. Particularly, the lower_bound is identical to upper_bound, while the range is exactly equal to the power of two. The threshold and shift_number are utilized to determine which sample should be encoded with upper_bound bit or lower_bound bit.

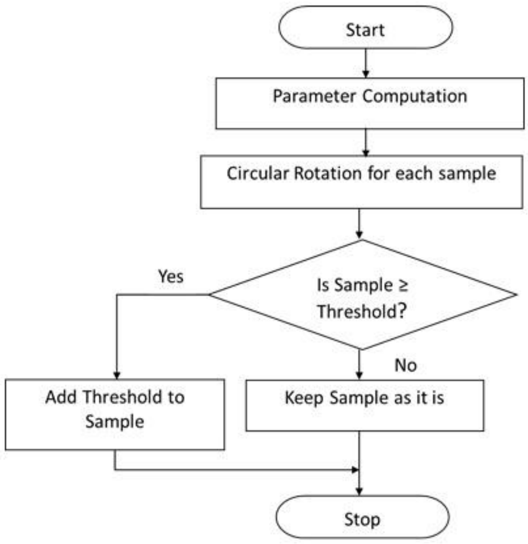


Fig.4 Flowchart for Adjusted Binary Coding

2.2 Golomb-Rice Code

For both above range and below range, the probability distribution sharply varies with exponential decay rate, and the efficient codeword should be more intensively assigned to the intensity with high probability. Therefore, Golomb–Rice code is adopted as the coding tool for both above range and below range. With Golomb-Rice code, the codeword of sample x is partitioned into unary and binary parts

Golomb-Rice code: - Unary part: $floor(\frac{x}{2k})$ (7)

Binary part: x % 2k (8)

where, k is a positive integer.

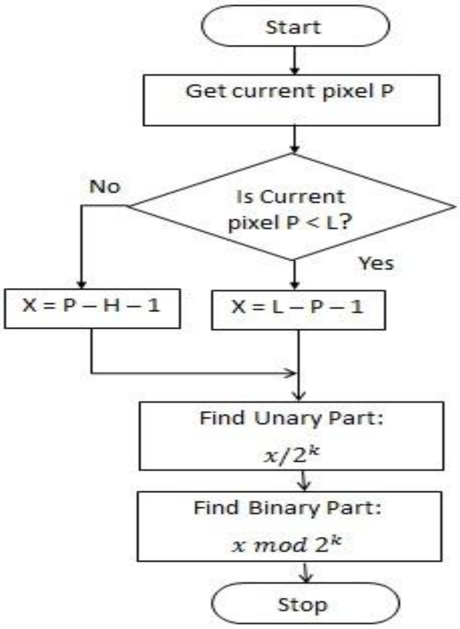


Fig.5 Flowchart for Golomb-Rice Coding

The entire codeword is concatenated with unary part and binary part, and one bit is inserted between both for identification.

3. Proposed Image Template for FELICS Algorithm

The proposed image template has five cases according to the position of the pixel in the image.

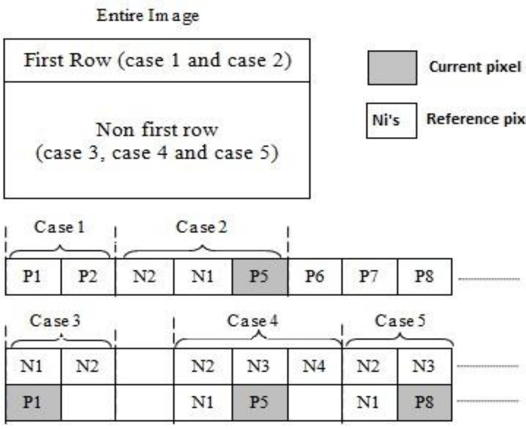


Fig.6 Modified Image Template

In case 1 the first two pixels in the image are sent without any modification. First two pixels are sent in fixed eight bit binary format for grayscale image. The case 2 is when pixels are in first row of image but not first and second, so case two applies from third pixel onwards till end of first row. Since the predictive technique is used for coding and decoding, so we require reference pixels. In case 2, the reference pixels are the pixels which are immediately adjacent to the current pixel to be encoded or decoded. The case 3 is applied for pixels present at left edge of image. For case 3, the reference pixels are the pixels which are to the top and top right of current pixel to be encoded or decoded. The case 4 is the new case which is proposed here. If the pixel is present anywhere other than first row or left edge or right edge of image, then case 4 is applied. In case 4, four reference pixels are taken, first the immediate left pixel, second top left pixel, third top pixel and fourth top right pixel.

4. Image Quality Parameters

For comparing the results obtained after using two different image templates we have considered various image quality parameters such as Compression Ratio (CR), Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR), Normalized Cross-Correlation (NCC), Average Difference (AD), Structural Content (SC) and Normalized Absolute Error (NAE) (V.S.Vora, *et al*, 2010). Here for calculating various image quality parameters original image matrix and compressed image matrix are used. $I_1(m,n)$ indicates an element of original image matrix and $I_2(m,n)$ indicates an element from compressed image matrix. Also M and N indicate the number of rows and columns of image matrix. For calculating the image quality parameters the dimensions of original and compressed images must be same.

4.1 Compression Ratio (CR)

The compression ratio is calculated as the ratio of the file size of original image to file size of reconstructed image.

$$CR = \frac{Original\ Image\ file\ size}{Compressed\ Image\ file\ size} \quad (9)$$

Higher value of compression ratio indicates that the reconstructed image is more compressed. As the compression ratio increases the quality of image degrades.

4.2 Mean Square Error (MSE)

The Mean Square Error is defined as,

$$MSE = \frac{\sum_{M,N}[I_1(m,n)-I_2(m,n)]^2}{M*N} \quad (10)$$

The larger the value of MSE poor is the quality of image.

4.3 Peak-Signal to Noise Ratio (PSNR)

Peak Signal to Noise Ratio (PSNR) is defined as,

$$PSNR = 10\log_{10}(\frac{255^2}{MSE}) \quad (11)$$

PSNR should be as high as possible, low value of PSNR means the image quality is poor.

4.4 Normalized Cross-Correlation (NCC)

Normalized Cross-Correlation (NCC) is defined as,

$$NCC = \frac{\sum_{M,N}[I_{1(m,n)}.*I_2(m,n)]}{\sum_{M,N}[I_1(m,n).*I_1(m,n)]} \quad (12)$$

Value of NCC close to 1, means the image quality is good.

4.5 Average Difference (AD)

Average Difference is defined as,

$$AD = \frac{\sum_{M,N}[I_1(m,n) - I_2(m,n)]}{M*N} \tag{13}$$

The large value of AD means that the pixel values in the reconstructed image are more deviated from actual pixel value. Larger value of AD indicates image is of poor quality.

4.6 Structural Content (SC)

Structural Content is defined as,

$$SC = \frac{\sum_{M,N}[I_{1(m,n)}.*I_1(m,n)]}{\sum_{M,N}[I_2(m,n).*I_2(m,n)]} \tag{14}$$

The large value of Structural Content (SC) means that image is of poor quality.

4.7 Normalized Absolute Error (NAE)

Normalized Absolute Error (NAE) is defined as,

$$NAE = \frac{\sum_{M,N}[abs(I_1(m,n) - I_2(m,n))]}{\sum_{M,N}[I_1(m,n)]} \tag{15}$$

Value of NAE close to 0, means the image is of good quality.

4.8 Bitrate

Bitrate is the ratio of total number of bits required to represent or transmit an image to the total number of pixels in that image. In other words, bitrate is nothing but average number of bits required to represent a single pixel. If bitrate is higher, then more number of bits are required to represent an image.

4. Experiment Results and Discussions

Here in this paper, a same image is compressed by FELICS algorithm, but with two different image templates. First technique consists of FELICS algorithm with original image template, while second technique is the proposed technique which consists of FELICS algorithm with modified image template.

This experiment is carried out on different class of images these images are taken from the website http://sipi.usc.edu/database and the performance of these techniques is compared on the basis of various image quality measures such as Compression Ratio (CR), Mean Square Error (MSE), Peak-Signal to Noise Ratio (PSNR), Normalized Cross-Correlation (NCC), Average Difference (AD), Structural Content (SC), Normalized Absolute Error (NAE) and Bitrate.

Table 1 Comparison of Image Quality Parameters for Lenna image

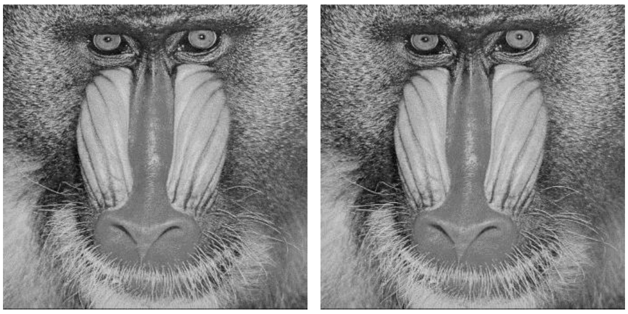
Image Quality Parameters	**Lenna image**	
	With original image template	**With modified image template**
CR	1.72	1.79
MSE	0	0
PSNR	99	99
NCC	1	1
AD	0	0
SC	1	1
NAE	0	0
Bit rate	4.2590	4.0544

(a) (b)

Fig.7 Results for Image of Lenna (a) with original image template (b) with modified image template

Table 2 Comparison of Image Quality Parameters for Baboon image

Image Quality Parameters	**Baboon image**	
	With original image template	**With modified image template**
CR	1.26	1.34
MSE	49.222	49.222
PSNR	31.209	31.209
NCC	0.998	0.998
AD	0.001	0.001
SC	0.999	0.999
NAE	0.414	0.414
Bit rate	6.1599	5.7453



(a) (b)

Fig.8 Results for Image of Baboon (a) with original image template (b) with modified image template

Table 3 Comparison of Image Quality Parameters for Boat image

Image Quality Parameters	Boat image	
	With original image template	**With modified image template**
CR	1.55	1.61
MSE	0	0
PSNR	99	99
NCC	1	1
AD	0	0
SC	1	1
NAE	0	0
Bit rate	4.7714	4.5892

(a) (b)

Fig.9 Results for Image of Boat (a) with original image template (b) with modified image template

Conclusions

1) By modifying the image template, we can get slightly higher compression ratio.
2) The image compressed by using modified template, has the same image quality parameter values as that compressed with original template.
3) The bitrate of the image compressed with modified template is lower than the image compressed with original template.
4) Since the bitrate is reduced, the average number of bits per pixel are also reduced, hence time required to transmit such images will also be reduced.
5) From the results obtained, it could be deduced that modified image template can be used to slightly increase the compression ratio and slightly decrease the bitrate, without affecting the quality of image.

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