EAI Endorsed Transactions
on Scalable Information Systems

Research Article **EAI.EU**

Empirical Evaluation of Coding and Inter Pixel Redundancy in still Image Compression

Anitha S[1,*], Kavitha J[2]

[1] Department of Computer Application, Govindammal Aditanar College for Women, Tiruchendur, Tamilnadu, India
[2] Department of Computer Science & Engineering, Vel Tech Rangarajan Dr.Sagunthala R&D Institute of Science and Technology, Avadi, Chennai, Tamilnadu, India

Abstract

The main aim of this research work is to compress grayscale images efficiently using prediction and intensity-based image compression algorithms. Image compression is useful for removing the duplication in an image to store and transmit the data in an efficient form. This research work analyzes four new schemes for gray scale lossy image compression. Among the four schemes considered, two compressive approaches are designed for Prediction Based Image Compression (PBIC) level implementation. Third approach is designed for Intensity Based Image Compression (IBIC). Finally, the previously designed PBIC and IBIC schemes lead to an Integrated Encoder. All the considered method performances are analyzed using the performance metrics. These results are compared with JPEG 2000 which is a extensively used benchmark compression encoder. The outcome of all the proposed methods is also compared with modern encoders.

Keywords: Prediction based Image Compression, Intensity based Image compression, Intra Prediction, Modulus Transformation, Integrated Encoder, octagon based intra prediction, neighboring block, JPEG 2000

Received on 17 November 2023, accepted on 26 January 2024, published on 05 February 2024

doi: 10.4108/eetsis.5029

*Corresponding author. Email: anithajayakodi@gmail.com

1. Introduction

Visual information is of vital importance for mankind to perceive and understand the surrounding world. The saying “A picture is worth a thousand words” rightly expresses the amount of information contained in a single image. As the transmission and storage of every single bit in an image incurs a cost, the necessity of cost-effective image compression technique plays an important role. There are various compression methodologies that are designed in the last several decades. It starts with grayscale image, followed by color image and the research has its path in video compression (both grayscale and color). Predictive coding can be made superiorly with the help of the compression ratio. Some researchers describe prediction-based lossless compression [1–5]. The research work that was proposed previously for grayscale image compression is analyzed in this paper.

The following research works are considered in this paper:

- An Octagon Based Intra Prediction (OBIP) scheme in PBIC method.
- N-Modulus Transformation (NMT) in PBIC method.
- IBIC – The impact of pixel values over compression is studied by dividing the image into high and low intensity values. Various existing compression methods are analyzed in this method.
- The Integrated Encoder.

The results of the above four methods are analyzed and compared with JPEG 2000 and recent encoders.

2. Literature review

As these presents removal of coding and inter pixel redundancy, review related to prediction and intensity-based image compression is elaborately discussed. The following sections discuss various compression algorithms and the research carried out by various researchers. The prediction coding is the majority straightforward for encode & decode. It moreover gives little computational difficulty. Some prediction-based lossless compression was studied in [6–8]. Moreover, the combination of wavelet transforms, and the idea of prediction is accessible in several studies [9-10]. Lohitha et al. [11] has proposed a novel scheme namely “Color Image Compression Using Hierarchical Prediction of Pixels.” In this work the picture pixels are predicted by a hierarchical prediction method after that the wavelet transform is put into the error of prediction.

Several efforts [12–18] apply to the variety of image conversion or pixel dissimilarity or straightforward entropy coding. The input image was first divided into non overlapped blocks based on the predefined threshold values. It is clear from the literature the bit rate can be condensed by the low variation blocks. But it is fewer efficient in falling PSNR for a picture that holds a large amount consistent scene of small variation areas. Wavelet base image compression is studied in [19-20]. Lifting or bi orthogonal wavelet transform is used. Set Partitioning in Hierarchical Trees limit the image energy to fewer coefficients. In Intensity oriented Adaptive Quantization Coding image is divided into high & low intensity blocks. High intensity encoding requires large quantization steps. Low intensity encoding does not need any quantization steps.

Some researchers describe Hybrid image compression which is evolved from on Discrete Wavelet Transform and JPEG standard. The wavelet coefficients in each subband are JPEG coded in different ways. Wei et al. [21] have described an image compression algorithm. Mishra et al. [22] have proposed common image compression techniques suitable for deep architecture. The paper pinpoints the troubles handled in the victorious execution of deep learning in picture compression.

3. Analyzed Methods

This section gives a brief description of the analyzed methods. It starts with the two PBIC methods, OBIP, NMT followed by IBIC and ends with integrated encoder.

3.1. OBIP design pattern

In PBIC technique, the intra prediction system is customized by OBIP design model. The picture is separated into N x N sectors. For N x N sector, comparable sectors are finding from the predicted sectors. In OBIP, the square and octagon searching scopes are presented. The search scope of the OBIP technique is shown in Figure 1. The inside square search scope occupies nine scopes for intra prediction & marked with shady gray even as the outside octagon search scope is marked with glow gray and it occupies twelve blocks for intra prediction. The comparison of the blocks is calculated by Block Distortion Measure (BDM). The scope through the least amount BDM is elected as the predicted block. The applicant block by means of lowest amount BDM is the one that coordinate with the current block. Algorithm 1 present the detail about octagon based intra prediction mode selection.

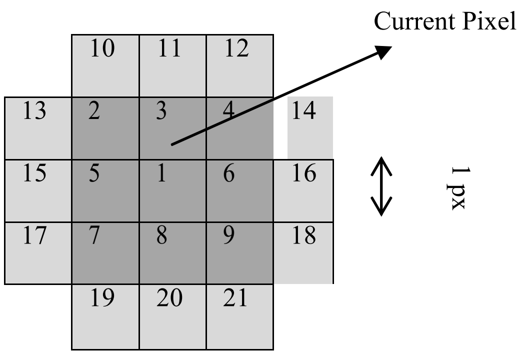

Figure 1. Octagon and Square search

The input to this algorithm is the input image and the prediction error is the output. The BDMsq is first calculated for all the search ranges in the square pattern. If any of the BDM is 0, then the predicted block is identified. Otherwise, the minimum value of this pattern is identified as BDMminsq. Similarly, the BDMoct is calculated for all the search ranges in the octagon pattern from which the minimum is calculated as BDMminoct. If the minimum BDM in the octagon range is 0, then the predicted block is identified. Otherwise, these two minimum values i.e. BDMminsq and BDMminoct are compared to obtain the prediction block. After identifying the prediction block, it is reduced from the current block to obtain the prediction error. The octagon and square range coordinates are discussed later in this chapter. Those coordinates are also defined before executing the algorithm. The pixel coordinates of the square and octagon range are described by having the encoding pixel as (0, 0). The square ranges as Square Search Pattern (SSP) and octagon ranges are defined as Octagon Search Pattern (OSP).

***Algorithm 1 :** Octagon Based Intra Prediction Mode Selection*

***Input:** Input Image*

***Output:** Prediction Error*

Steps:

1. *For each block b in input image*

   For each block c in square range,

   $BDM_{sq} = BDM(b, c)$

   If $min(BDM_{sq}) = 0$

   Predicted block = c

   Go to Step 1.7

   End

   End

   $BDM_{minsq} = min(BDM_{sq})$

   For each block c in octagon range,

   $BDM_{oct} = BDM(b,c)$

   If $min(BDM_{oct}) = 0$

   Predicted block = c

   Go to Step 1.7

   End

   End

   $BDM_{minoct} = min(BDM_{oct})$

   $BDM_{min} = min(BDM_{minsq}, BDM_{minoct})$

   Obtain Predicted Block from BDM_{min}

   Prediction error (b) = Current block (b) - Predictedblock (b).

2. *End*

The square range pattern is described as

SSP(1,:) = [0 0] SSP(6,:) = [0 1]
SSP(2,:) = [-1 -1] SSP(7,:) = [-1 1]
SSP(3,:) = [0 -1] SSP(8,:) = [0 1]
SSP(4,:) = [1 -1] SSP(9,:) = [1 1]
SSP(5,:) = [-1 0]

The octagon range pattern is described as

OSP(10,:) = [-1 - 2] OSP(16,:) = [2 0]
OSP(11,:) = [0 - 2] OSP(17,:) = [-2 1]
OSP(12,:) = [1 -2] OSP(18,:) = [2 1]
OSP(13,:) = [-2 -1] OSP(19,:) = [-1 2]
OSP(14,:) = [2 -1] OSP(20,:) = [0 2]
OSP(15,:) = [-2 0] OSP(21,:) = [1 2]

3.2. NMT in OBIP (NMT-OBIP)

The correlation between pixels is increased using modulus method. An intra coding fully depends on spatial redundancy, compression performance can be increased if the correlation between pixels is increased. In this method, the pixels in the image are changed to different values which are divisible by a common number, say N (N=2 to 9). Then by dividing the pixels by N, gives the pixels which are more correlated. The 5 x 5 block to be encoded is outlined in Figure 2.

126	*124*	*126*	*124*	*124*	*126*	*128*	*130*	*130*	*126*
126	127	126	127	124	128	130	131	129	128
126	126	126	126	127	128	129	131	129	129
127	125	127	125	124	126	130	130	129	130
126	126	126	126	124	128	132	130	130	130
126	125	126	125	124	128	132	130	130	130
126	125	126	125	124	128	131	130	129	130
125	126	125	126	127	128	130	132	131	130
126	125	126	125	124	129	131	130	129	130
125	126	125	126	127	128	130	132	131	130

Figure 2. Sample block for intra coding

The similar 5 x 5 block is not found around this block. After applying NMT-OBIP, almost all pixels have the same value which leads to spatial redundancy. Now the block can be easily encoded using intra prediction. The encoded block is shown in Figure 3. In Figure 3, the 5 x 5 block has the match below it. Using this method, N modulus transformation can be done to increase the redundancy among pixel values. In this section, NMT method has been explained and a new model is proposed by applying the OBIP mode selection algorithm using NMT.

25	25	25	25	25	25	26	26	26	25
25	25	25	25	25	26	26	26	26	26
25	25	25	25	25	26	26	26	26	26
25	25	25	25	25	25	26	26	26	26
25	25	25	25	25	26	26	26	26	26
25	25	25	25	25	26	26	26	26	26
25	25	25	25	25	26	26	26	26	26
25	25	25	25	25	26	26	26	26	26
25	25	25	25	25	26	26	26	26	26
25	25	25	25	25	26	26	26	26	26

Figure 3. Correlation between blocks

Analysis has been carried out by varying the „N" value in the range 2 to 9. The modulus transformation is converted to a more general form to adapt the pixel value in the image. Since intra prediction is efficient if the neighbour blocks have same pixel values, NMT can be integrated with intra prediction called as NMT-OBIP to improve the efficiency.

Algorithm: 2 N Modulus Transformation

Input: *Image*
A, N ***Output:***
Modified
*Image****Steps:***
1. s=N/2
2. for i=1 to row size
3. for j=1 to
column
sizefor
k=1 to
s
if mod(A(i,j),N)==(N-k)
3.1.1.1 A(i,j)=A(i,j)+k
End
End
4. end
5. for
k=(s+1) to Nif
mod(A(i,j),N)==(N-
k)
5.1.1 A(i,j)=A(i,j)-(N-k)
End
6. end

In Algorithm 2, the pixel value is rounded to the value that is divisible by N. If a number is to be rounded, either ceil or floor has to be used. The two loops in the algorithms reveals ceil and floor functions. For ceiling or flooring, the middle value of N is needed. Hence, it is calculated in Step 1. Here, the modulus operation is generalized based on the value of N.
In IBIC method, the input image is splitted on the thresholding value of 125. All the black and white picture values variety from 0-255. High Intensity (HI) consists of all the pixel values >=125. Low Intensity (LI) components consist of all the pixels <125. After segmenting the image into HI vector and LI vector with pixel values based on threshold, the HI and LI pixels are processed separately using different existing algorithm. High intensity pixels are encoded using three compression methods viz Discrete Cosine Transform (DCT), Singular Valued Decomposition (SVD) and JPEG 2000 encoder, along with the low intensity pixels are left as such. The best from the three algorithms for high intensity pixels is chosen. The low intensity pixels are encoded using another three different compression methods viz Arithmetic Encoding (AE), Vector Quantization (VQ) and Quad-tree Decomposition (QD) algorithm along with high intensity pixels are left as such. After decoding the small intensity pixels, the elevated intensity pixels are synthesized on the way to get the output image. Among the three compression methods, the best one is chosen based on their performance metrics. The Algorithm of IBIC method is given below.

3.3. Intensity Based Image Compression

In IBIC method, the input image is splitted on the thresholding value of 125. All the black and white picture values variety from 0-255. High Intensity (HI) consists of all the pixel values >=125. Low Intensity (LI) components consist of all the pixels <125. After segmenting the image into HI vector and LI vector with pixel values based on threshold, the HI and LI pixels are processed separately using different existing algorithm. High intensity pixels are encoded using three compression methods viz Discrete Cosine Transform (DCT), Singular Valued Decomposition (SVD) and JPEG 2000 encoder, along with the low intensity pixels are left as such. The best from the three algorithms for high intensity pixels is chosen. The low intensity pixels are encoded using another three different compression methods viz Arithmetic Encoding (AE), Vector Quantization (VQ) and Quad-tree Decomposition (QD) algorithm along with high intensity pixels are left as such. After decoding the small intensity pixels, the elevated intensity pixels are synthesized on the way to get the output image. Among the three compression methods, the best one is chosen based on their performance metrics. The Algorithm of IBIC method is given below.

Algorithm: 3 IBIC Algorithm

Input: *Image of size m x n,*

Output: *Reconstructed Decompressed Image of size m x n*

Steps:

1.Read Input Image
2.St1=False;
3.St2=False;
4.[n,n1]=find(α >=125)
Do DCT, SVD, JPEG 2000

B1=find_efficient (DCT,SVD,JPG2000)

5.[m,m1]=find(α <125)
Do AE, QD, VQ

B2=find_efficient(AE, QD, VQ)

6. if (α >=125)
Do B1

St1=True

7. End

8. If (α <125)

Do B2

St2=True

9. End

10.If ((st1==True)&& (st2==True))

Integrate B1 and B2

11. End

In Algorithm 3, α is used to identify any pixel in the image. The low intensity components are identified if α is lesser than 125. The high intensity components are identified if α is >= 125. This number is chosen as threshold based on empirical study. It is found that the HI components are efficiently encoded with JPEG 2000 and LI components are efficiently encoded with AE.

3.4. Integrated Encoder

The system architecture of integrated codec is shown in Figure 4. In that technique the picture is classified into high & low intensity pixels. Both PBIC and IBIC are integrated together to form an Integrated encoder.

From IBIC method, efficient encoders (JPEG 2000 for HI and AE for LI) are chosen for encoding HI and LI components. These encoders are combined with NMT-OBIP codec to design a novel codec. The integrated codec is carried out in two approaches. The encoder used in each approach is shown in Table 1.

Table 1. Encoder used in Approach 1 and 2

Approach	HI Component Encoder	LI Component Encoder
Approach 1	JPEG 2000	NMT-OBIP
Approach 2	NMT-OBIP	AE

In the Approach 1, HI components are encoded using JPEG 2000 encoder and LI components are encoded using the NMT-OBIP encoder. In Approach 2, HI components are encoded using NMT- OBIP and LI components are encoded using AE. Those two approaches of the Integrated Encoder are analysed in [34] and found that, the Approach 1 with HI JPEG 2000 and LI NMT- OBIP achieves better PSNR and BPP. Hence, Approach 1 is used for analysis.

4. Empirical Study

This section analyses all the four methods with the obtained results. It starts with a list of input images, performance metrics and the results analysis. The results analysis is done in two different ways. First, the four methods are compared with the compression standard JPEG 2000. Second, it is compared with other encoders.

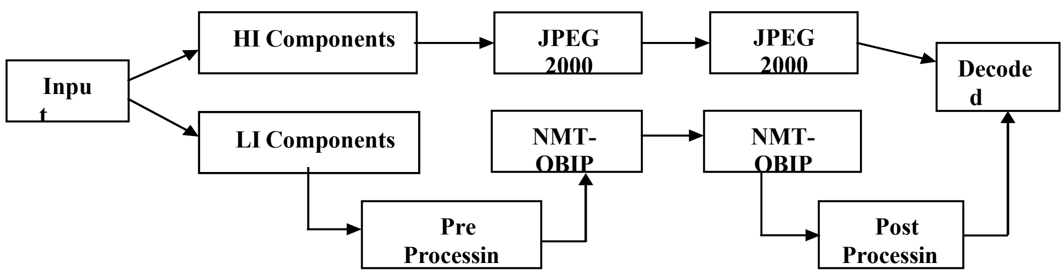

Figure 4. Architecture of Integrated Codec

4.1. Analysis of OBIP, NMT-OBIP, IBIC and Integrated Encoder with JPEG 2000

The performance of the four methods is compared with well-known JPEG 2000 image compression standard. JPEG2000 is the image compression standard for several years. Hence, it is necessary to compare the proposed methods with JPEG2000. The resulting average performance measures for considered images are recorded in Table 3.

Table 2. Summary of results obtained-Average Values compared with JPEG 2000

Performance Measures	OBIP	NMT-OBIP	IBIC	Integrated Encoder	JPEG 2000
CR	5.6325	14.52738	13.54225	13.94667	10.9699
PSNR	56.7008	52.285	54.84865	55.21833	51.7718
Bits Per Pixel	0.1923	0.090917	0.5930333	0.081	0.7337

It is perceived from the results (Table 2), that on an average the OBIP Encoder gives a compression ratio of 5.6325 leading to 0.1923 bit rate and it also maintains the PSNR value of 56.7008dB. In similar line, NMT-OBIP Encoder achieves an average of 14.52738 compression ratio leading to 0.090917 bit rate and it also maintains the PSNR value of 52.285 dB. IBIC Encoder gives an average compression ratio of 13.54225 leading to 0.5930333 bit rate and it also maintains the PSNR value of 54.84865 dB. Integrated Encoder achieves with an average of 13.94667 compression ratio leading to
0.081 bit rate and it also maintains the PSNR value of 55.21833 dB. JPEG 2000 Encoder gives an average compression ratio of 10.9699 leading to 0.7337 bit rate and it also maintains the PSNR value of 51.7718 dB. OBIP gives better PSNR value but compared to other methods it gives very low compression ratio. On the report of three performance measures all the four proposed methods have enhanced PSNR and bit rate values than JPEG2000. IBIC Encoder gives nearly equal PSNR value compared to Integrated Encoder but its bit rate values are inappreciable than Integrated Encoder. From the experiential outcome it is clear so as to improved compression ratio gives enhanced bit rate value.

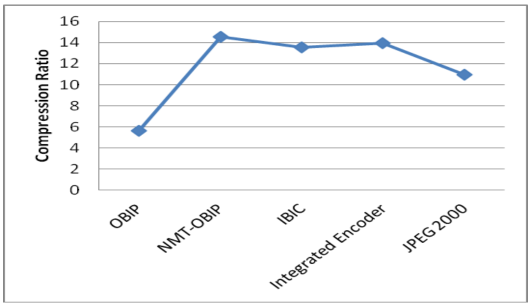

Figure 5. Compression Ratio of Analysed Methods with JPEG 2000

Figure 5 Shows that the compression ratio of proposed work with JPEG 2000. From the observed results it is clear that NMT-OBIP gives high CR value than all others. IBIC and Integrated Encoder gives nearly equal CR value. Figure 5 reveals that all the proposed methods encompass improved CR value except OBIP when compared with JPEG 2000. Table 3 compares the gain percentage of the analyzed methods with JPEG 2000.

Table 3. Gain % of four analyzed methods compared with JPEG 2000

Gain %				
Gain %	OBIP	NMT-OBIP	IBIC	Integrated Encoder
CR	No Gain (-48.65%)	32.43%	23.45%	27.14%
PSNR	9.52 %	0.991%	5.94%	6.66%

From Table 3, it is observed that there is no CR gain in OBIP. But it let have better PSNR gain % that is 9.52. NMT-OBIP gives CR gain % of 32.43 and PSNR gain % of 0.991. IBIC gives CR gain % of 23.45 and PSNR gain % of 5.94. Integrated Encoder gives CR gain % of 27.14 and PSNR gain % of 6.66. Integrated Encoder is extremely elevated when compared with all other analysed methods. From this table, it is evidently exposed that all the four analysed methods encompass improved PSNR gain than JPEG 2000. Table 4 gives space saving gain % of all the analysed methods compared with JPEG 2000.

Table 4. Space saving Gain % of four analyzed methods compared with JPEG 2000

Method	Gain in space saving (%)
OBIP	-9.5
NMT-OBIP	2.45
IBIC	1.91
Integrated Encoder	2.15

From Table 4, it is clearly evident that the NMT-OBIP, IBIC and Integrated Encoder have nearly equal gain in storage saving. When compared with JPEG 2000, all the methods except OBIP have gain in storage space saving. Figure 6 shows the average space saving % for all the four methods.

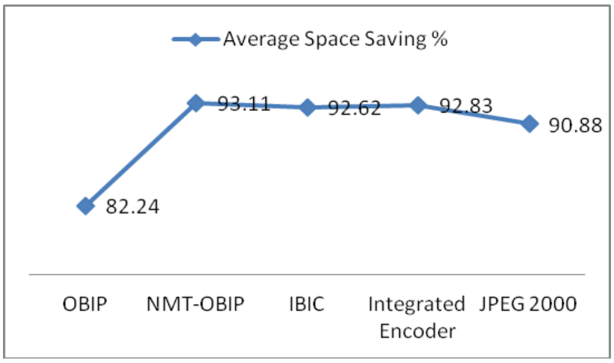

Figure 6. Comparision of Storage Space Saving %

From graph, it is clear that NMT-OBIP, IBIC and Integrated Encoder give nearly equal average space saving %. When compared with JPEG 2000, the NMT-OBIP, IBIC and Integrated Encoders have gained 2.45%, 1.91% and 2.15% space saving respectively. OBIP method does not save space when compared with JPEG 2000.

4.2. Integrated Encoder Compared with other Encoders

From the observed results in the previous subsection, it is clear that the improved CR yields better bit rate value. If Bit rate value is good, then it is evident that the encoder yields good image compression. So, the bit rate value of proposed Integrated Encoder is compared with all other basic and recent encoders. Basic Encoders such as BMA, TMW are used to evaluate the outcome of proposed Integrated Encoder. VBS, APC and ETC encoders are designed during the period of 2010, 2013 & 2014 respectively. The proposed OBIP, NMT- OBIP, IBIC and integrated codec is compared with all the above-mentioned algorithms in terms of BPP. The comparison chart is shown in Figure. 7.

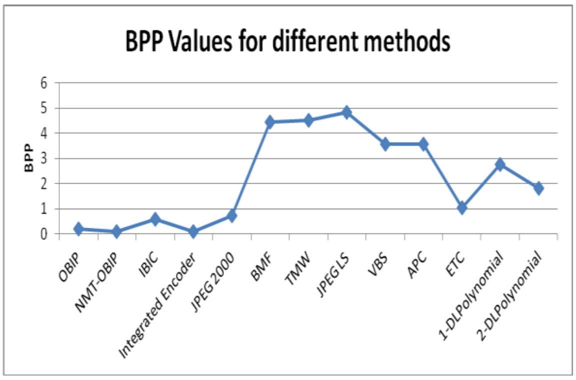

Figure. 7. BPP Comparison of Existing and Proposed Encoder

From Figure 7, it is clear that all the proposed methods have better bit rate values than other considered existing algorithms. Among the analyzed methods, NMT-OBIP method and Integrated Encoder use lesser bits for encoding.

5. Conclusion

The major confront in motionless image compression is reducing bytes of a picture without modifying the eminence of the image and also dropping the occupied space and bandwidth cost needs. This paper analyzed four methods in grayscale image compression: OBIP, NMT-OBIP, IBIC and Integrated Encoder. All the methods are analyzed using CR, PSNR and BPP. From the analysis, it is studied that Integrated Encoder possesses the strength of both PBIC and IBIC whilst maintaining the quality of JPEG 2000 encoder. It is found that Integrated Encoder is the best among the four methods considered. All the methods are also compared with other encoders and proved its efficacy.

References

[1] Koc, B, Arnavut, Z, Kocak, H. Lossless compression of dithered images. IEEE Photonics Journal, 2012, Vol.(5), pp.6800508-6800508.

[2] Kim, S, Cho, N, I. Hierarchical prediction and context adaptive coding for lossless color image compression. IEEE Transactions on image processing, 2013;Vol.(1), pp.445-449.

[3] Weinberger, M, J, Seroussi, G, Sapiro, G.The LOCO-I lossless image compression algorithm: Principles and standardization into JPEG-LS, IEEE Transactions on Image processing, 2000;Vol.(9), pp. 1309- 1324.

[4] Lucana, S. Performance evaluation of the H. 264/AVC video coding standard for lossy hyperspectral image compression. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 2011;Vol.(5), pp. 451-4611.

[5] Khafaji,A, l, Ghadah, Rajab, A. Lossless and lossy polynomial image compression. OSR J. Comput. Eng., 2016;Vol.(18), pp.56-62.
[6] Xiaolin, Lossless compression of continuous-tone images via context selection, quantization, and modeling. IEEE Transactions on Image Processing , 1997;Vol.(6), pp. 656-664.
[7] Amir,S, Pearlman, A. An image multiresolution representation for lossless and lossy compression, IEEE Transactions on image processing, 1996; Vol.(5), pp.1303-1310.
[8] Xin, L, Orchard, T. Edge-directed prediction for lossless compression of natural images. IEEE Transactions on image processing, 2011;Vol.(10), pp. 813-817.
[9] Zahhad, A. Huffman image compression incorporating DPCM and DWT. Journal of Signal and Information Processing, 2015; Vol. (6), pp.123.
[10] Lohitha, P, Ramashri, T. Color Image Compression Using Hierarchical Prediction of Pixels. Int. J. Adv. Comput. Electron. Technol, 2015;Vol. (2), pp.99-102.
[11] Saif, A, Borici, A. An innovative lossless compression method for discrete-color images. IEEE Transactions on Image Processing,2014; Vol. (24), pp. 44-56.
[12] Pralhadrao, V, Saravanan, K, N. Pixel size reduction loss-less image compression algorithm. International Journal of Computer Science & Information Technology, 2013; Vol.(5), pp.87.
[13] Suarjaya, I, M, A, D. A new algorithm for data compression optimization.2012; arXiv preprint arXiv:1209.1045.
[14] Hao, W. Lossless compression of JPEG coded photo collections. IEEE Transactions on Image Processing, 2016; Vol.(25), pp.2684-2696.
[15] Harsimran, K, Jindal, B. Lossless text data compression using modified Huffman Coding-A review. Proceedings of the International Conference on Technologies for Sustainability-Engineering, Information Technology, Management and the Environment. 2015; Vol.(11), pp.1017-1025.
[16] Kabir, M.A., Mondal,M. R,H. Edge-based and prediction-based transformations for lossless image compression. Journal of Imaging, 2018; Vol. (4), pp.64.
[17] Oshri, E., Shelly, N, Mitchell.H, N. Interpolative three-level block truncation coding algorithm. Electronics Letters, 199;Vol. (14), pp. 1267-1268.
[18] Adrian, M ,Cornelis, J, Cristea, p. Wavelet-based lossless compression of coronary angiographic images.IEEE transactions on medical imaging, 1997;Vol. (18), pp. 272-281.
[19] Taujuddin, N. S. A. M., IBrahim, R, Sari, S. Progressive Pixel-to-Pixel Evaluation to Obtain the Hard and Smooth Region for Image Compression. 6th International Conference on Intelligent Systems, Modelling and Simulation. IEEE, 2015.
[20] Han, O, Bilgin,A, Marcellin, M. Visually lossless encoding for JPEG2000. IEEE Transactions on Image Processing, 2012;Vol. (22), pp.189-201.
[21] Wei, Z, Lijuan, S, Guo, H, Linfeng, J.Image compression scheme based on PCA for wireless multimedia sensor networks, The Journal of China Universities of Posts and Telecommunications, 2016;Vol.(23), pp. 22-30 .
[22] Mishra, D, Singh, S, K, Singh,R, K. Deep Architectures for Image Compression: A Critical Review, Signal Processing, 2022;Vol. (191), pp.108346.