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Novel ESNIU upsampling method for lossy image compression

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Abstract

Lossy image compression is an attractive field for researchers. Image interpolation and demosaicking concepts can induce the higher compression ratio of lossy image compression. This paper proposes an image compression method which comprises of the Novel scheme for image-upsampling namely 'Error Signal Constrained Neighbor based image upsampling (ESNIU)'. The existing demosaicking method namely 'Multiscale Gradients based color filter array Demosaicking (MGD) is employed to achieve the demosaicking. The combination of these two methods emerge the high-grade proposed method for lossy image compression and the new method is abbreviated as ESNIU-MGD. In this paper, the main contribution ESNIU upsampling is designed to effectively handle the Green-Error signals for upsampling with the aid of neighbour pixels. The experimental results show that the proposed ESNIU-MGD method makes significant positive enhancement in both cases of quality and compression ratio. The PSNR and CR of the ESNIU-MGD proves the promising enhancements than the existing lossy image compression methods.

Keywords

Lossy image compression, image upsampling, demosaicking, ESNIU-MGD, compression, color filter array

I Introduction

The main purpose of image compression is to reduce the size of an image. It can compress the repetitive data sequences. Compression enables effective storage and management of data. Image Compression used two difference techniques, lossless compression and lossy compression [1]. In Lossless Compression after decompression data can be restored and rebuilt in its original form. Lossless Compression is also termed as reversible compression. Data-holding capacity is loss compared to lossy compression. For text, images and sound lossless compression can be used. In algorithm used in lossless compression are Run length encoding, Lempel-Ziv-Welch, Huffman coding Arithmetic encoding etc [2]. The lossy Compression can reduces the size of data using algorithms such as Discrete Cosine Transform, Discrete Wavelength Transform, Fractal Compression etc. The lossy compression can be applied in images, audio and video. Data holding capacity is higher in lossy compression. Lossy compression is also termed as irreversible compression [3]. The main issues of lossy compression is lost data is not retrievable. When data is removed it can only be edited with small changes without causing further damage. They are widely used in MP3 audio, JPEG image, MPEG videos. It services on various application such as steaming media, telephony internet [4] [5], Medical imaging, Law forensics, Military imagery, Satellite imaging etc. This method improves the network lifetime when the communication is occurred [31][32][33].

The paper [6] describes a color image interpolation for high resolution acquisition and display devices. The demerit of this interpolation method is the mitigated quality of resized image. An Image Interpolation scheme is designed in [7], which presents an image interpolation system which supports for the digital camcorder. Hard-thresholds are used here which is also a demerit. The paper [8] presents an image resampling method based on quadratic functions. The mitigated interpolation quality is the fault of this method. An Image Interpolation scheme is designed in [9] and that reveals an image resizing method for medical images and natural images. The misfortune of this method is that it can’t be worth-full for complex images. The paper [10] reports an image interpolation scheme for natural image. The insignificance of this method is the intolerance against salt and pepper noise. The paper [11] puts forth an image interpolator to zoom the images into the 2x mode. The Limited edge-patterns are the failure of this method. An Image Interpolation scheme is designed in [12], which comes forth with an edge directed interpolation scheme. The parts other than edge area are suffered by blur artifact which is known as the weakness of this method. The paper [13] derives an interpolation method for de-interlacing. The imperfection of this method is the less PSNR related with interpolation. The paper [14] presents two image-resizing methods using Local Gradient Features (LGF). The PSNR value is not competed to the modern methods which is also a smallness of this method. An Image Interpolation is developed in [15] to upsample the natural images. The demerit is that this method has not tested with standard database images.

The paper [16] develops a lossy image compression method using two wavelet filter banks. The failure is the artifact generation in the shape of line-like objects. A natural image compression scheme is described in [17] which works based on Down-Sampling method. The edge locations face a little level of blur which is the other misfortune. The paper [18] codes an image compression method for Computed Tomography (CT) images. This method has not tested for color images, which is known as the drawback. A lossy image compression is published in [19] for texture filling in missing image blocks. The imperfection is the block artifact while making compression. The paper [20] puts forth a lossy compression approach for volumetric medical datasets. The smallness is the high memory occupation and slow execution. An image compression scheme is focused in [21] with an automatic quality control for medical image sequences compression. The performance study has not been done on other images excluding medical images, which is known as the meanness. The paper [22] presents a lossy coding for satellite images using the lifting scheme. This scheme is designed using global concept, meaning that absence of local computation leads less performance related to compression ratio which is the fault. The Discrete wavelet transform (DWT) based lossy compression is coded in [23] for natural images. This method is not fit to low-bit rate images which is also a disadvantage of this scheme. The DCT quantization noise model is constructed in paper [24] to compression the natural image in lossy mode. The demerit is that the compression ratio is lesser than the JPEG2000 method. The paper [25] publishes an image compression method in the lossy mode for grayscale images. The supra-threshold contrast parameter is derived from very few images which is the demerit.

The state-of-the-art literature in lossy image compression shows the challenges to design a new compression method. The core issues of lossy image compression method are less Peak Signal to Noise Ratio (PSNR) and less compression ratio (CR). To solve the demerits of the existing methods, this paper design a new image compression method namely ESNIU-MGD. The pre-eminent output of the proposed method is due to the two methods such as ESNIU upsampling method and MGD method. The ESNIU upsampling is a new method to effectively upsample the color image using the Green-Error Signal and neighbour pixel data.

The section 2 deeply explains the methods involved in the proposed method. The section 3 analyses and discusses the outputs, and assess the performance metrics. The section 4 speaks about the pixel of this research.

II Proposed Method

The proposed method ESNIU-MGD compresses the image data into a compressed file and reconstruct it to the original image form using the uncompression techniques influenced by ESNIU upsampling and MGD demosaicking, with the acceptable range of data loss. This compression method can be well explained by stating it with two parts such as compression section and decompression section.

The compression section of the ESNIU-MGD method consists of the steps to attain the compressed data. The overall process of the compression section is showcased in Figure 1.

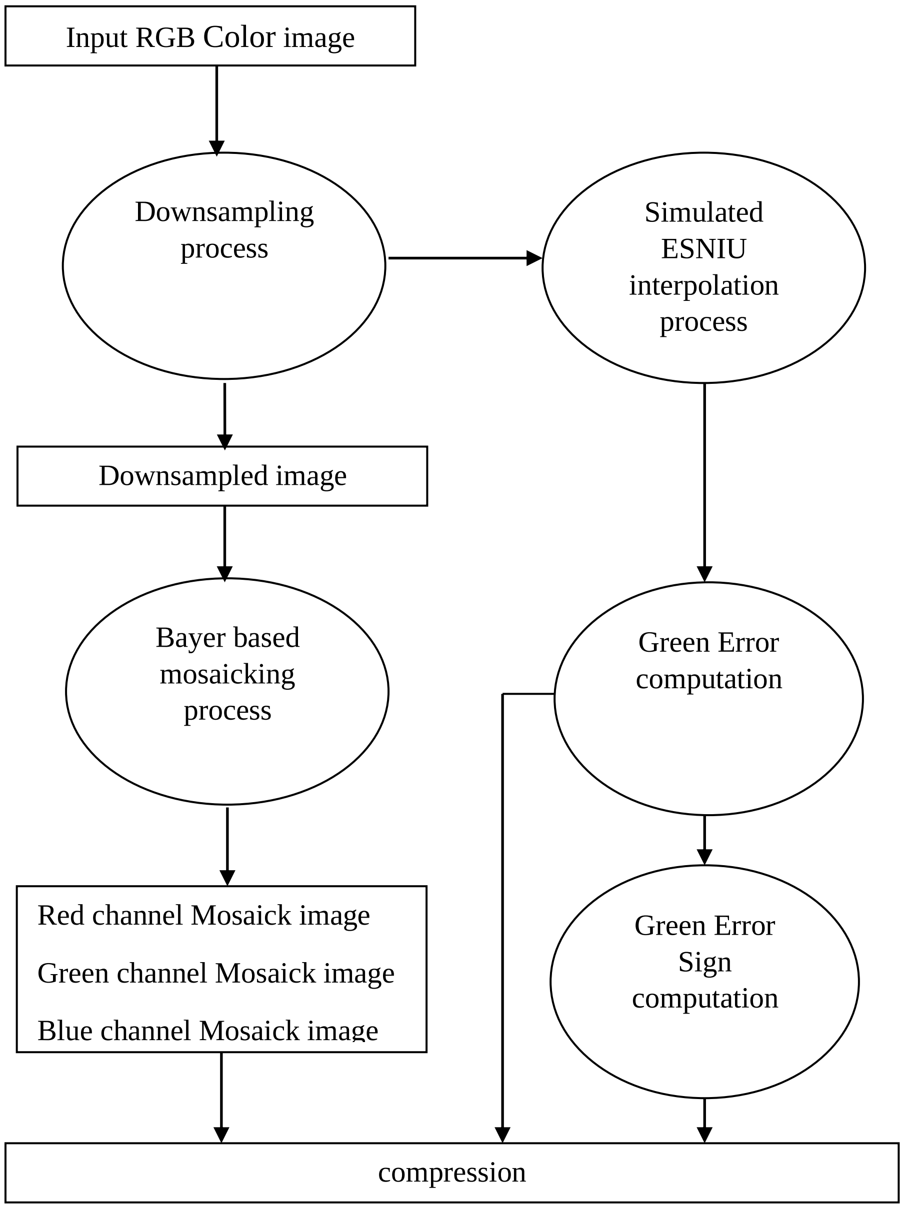


Fig.1: Flow diagram of the Compression section of the proposed ESNIU-MGD method.

The input color image is fed as input to this method. The input image is downsampled using pixel-based technique. The 4 x 4 size non-overlapped block yield a single value as the pixel corresponding to the downsampled image. The downsampled image is kept as in the half size of the original image size.

The simulated ESNIU interpolation is performed using the downsampled image. The compression side ESNIU upsampling process is divided into sections and they are:

- Predictor data filling
- Diagonal direction estimation
- Horizontal direction estimation
- Vertical direction estimation

The first stage-interpolated image I_0 is drawn out by placing the downsampled pixel-data at the predictor-location. The multi-diagonal image I_1 is formed using both the main-diagonal and secondary diagonal. The main-diagonal based interpolated image I_2 is formed using the average of the two main diagonal elements. Likewise the secondary-diagonal based interpolated image I_3 is formed using the average of the two secondary diagonal elements. The final diagonal based image is generated using Equation (1).

$$I_D = \frac{I_1 + I_2 + I_3}{3} \quad (1)$$

Where I_D –Diagonal interpolated image

The horizontal interpolated image I_4 is estimated using the help of the both left and right elements using the averaging process. The Left element based interpolated image I_5 is estimated using the help of the left element. The right element based interpolate image I_6 is estimated using the help of the right side element. The averaging process of these three elements are noted as the horizontal diagonal image which is expressed in Equation (2).

$$I_H = \frac{I_4 + I_5 + I_6}{3} \quad (2)$$

Where I_H –Final Horizontal interpolated image

The vertical interpolated image I_7 is estimated using the help of the both Top and Bottom elements using the averaging process. The Top element based interpolated image I_8 is estimated using the help of the Top element. The Bottom element of based interpolated image I_9 is estimated using the bottom pixel.

$$I_V = \frac{I_7 + I_8 + I_9}{3} \quad (3)$$

where

I_V = Final vertical interpolated image

The combination of the four images I_0, I_D, I_H and I_V constructs the ESNIU upsampling image at compression side.

The Green-Error data is computed by subtracting the upsampled-green-version image from the original-green-image. The sign of Green-Error image is extracted and stored separately.

The downsampled image is undergone the Bayer-based mosaicking process. The mosaicking pattern of Bayer is revealed in Figure 2.

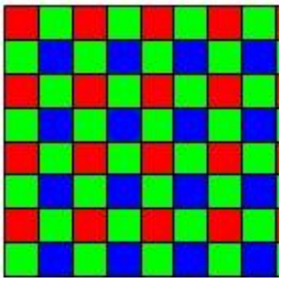
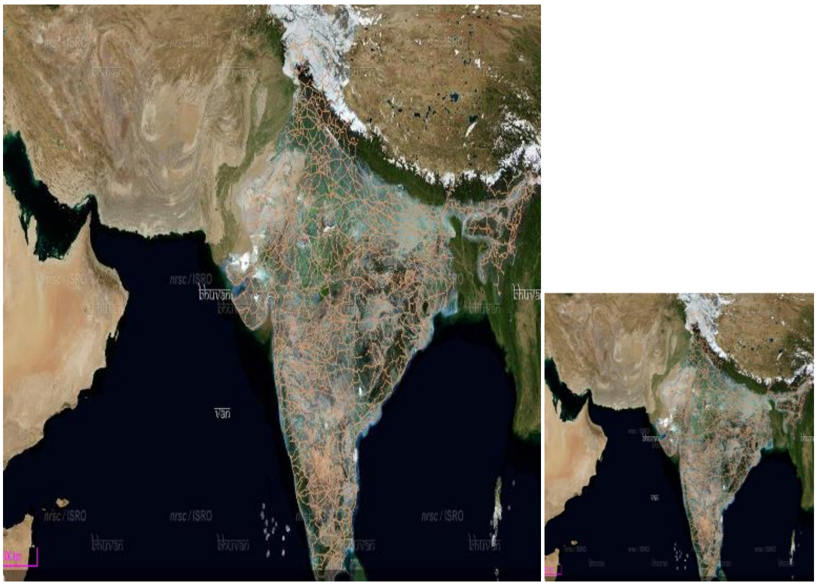


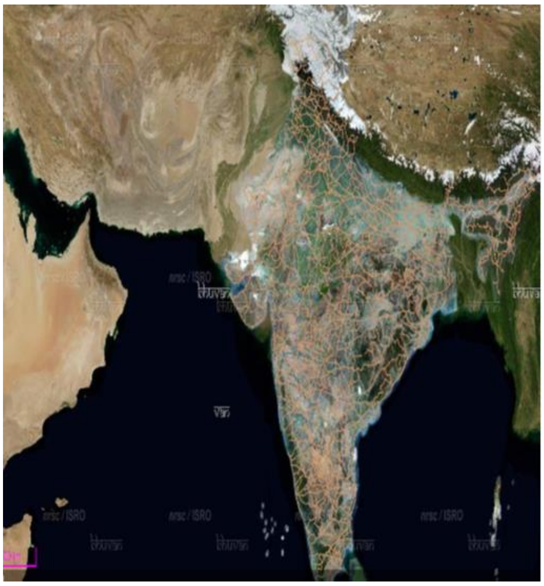
Fig:2; Illustration of Bayer pattern.

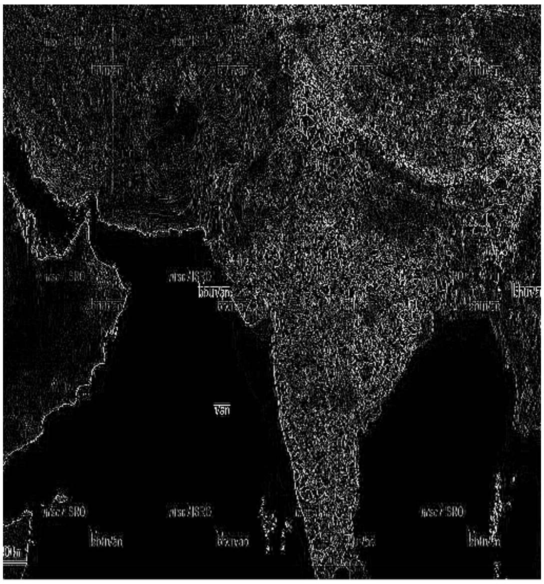
The demosaicking process reduces the dimension of the three-color-channel image into the single-color-channel image. The Bayer pattern specifies which color data should be maintained for a specific pixel instead of the three-color-data. The Red channel images is extracted from the downsampled color image based on Bayer pattern. The Green channel image is extracted from the downsampled color image. In this way the Blue color image is also extracted. The dimension of mosaicked Red image is $\frac{H}{4}\ x\ \frac{W}{4}$. Likewise, the dimension of mosaicked Blue image is $\frac{H}{4}\ x\ \frac{W}{4}$.

The mosaicked Red image, mosaicked Green image, mosaicked Blue image, Green-Error and Green-Error-Sign data are stored in the compressed file. The Figure 3 reveals the outputs of the compression section of the proposed method.

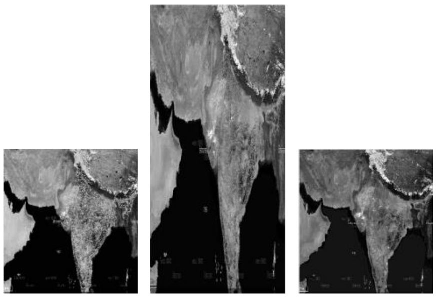


(a) (b)





(c) (d)



(e) (f) (g)

Fig.3: Sample outputs of compression section of ESNIU-MGD method for Sat_img1: a) Input color satellite image, b) Downsampled image, c) Simulated ESNIU interpolation image, d) Green Error image, e) Bayer pattern based Red image, f) Bayer pattern based Green image, g) Bayer pattern based Blue image.

The decompression section of the ESNIU-MGD method is initiated by uncompressing the compressed data. The overall flow diagram of the proposed method's decompression is given in Figure 4. The elements such as mosaicked Red image, mosaicked Green image, mosaicked Blue image, Green Error and Green-Error-Sign data are extracted from the compressed file.

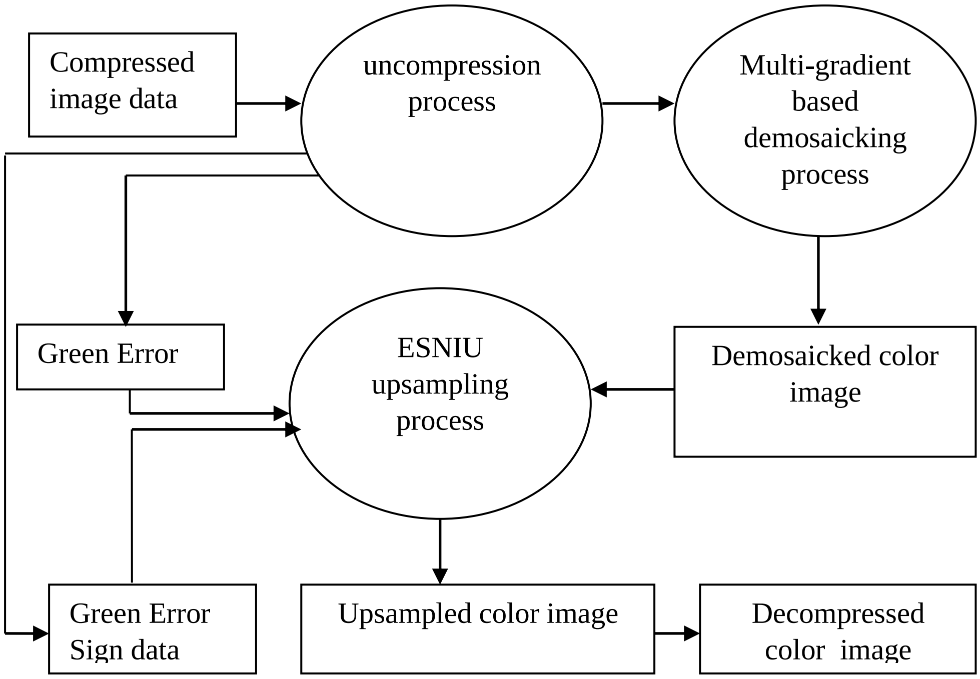


Fig.4: Flow diagram of the Decompression section of the proposed ESNIU-MGD method.

The multi-Gradient based demosaicking process is proceeded using the mosaicked version of the Red, Green and Blue images. The R,G,B images are converted into Bayer based mosaicked form. This MCD demosaicking method consists of three steps and they are:

- Green computation in R & B locations
- R & B computation in G locations
- R & G computation in non-green locations

The MGD demosaicking is given in detailed in [30]. The horizontal-Green image is generated using the location of R & B. The vertical-Green image is generated using the location of R & B. The horizontal chrominance is computed using Equation (4).

$$\mathbf{I}_{\mathbf{HC}}^{\mathbf{i,j}} = \begin{cases} \mathbf{R}^{\mathbf{i,j}} - \mathbf{G}_{\mathbf{HR}}^{\mathbf{i,j}}, & \textbf{if } \mathbf{mod}(\mathbf{i},\mathbf{2}) = \mathbf{0} \;\&\; mod(\mathbf{j},\mathbf{2}) = \mathbf{0} \\ \mathbf{B}^{\mathbf{i,j}} - \mathbf{G}_{\mathbf{HR}}^{\mathbf{i,j}}, & \textbf{else if } \mathbf{mod}(\mathbf{i},\mathbf{2}) = \mathbf{1} \;\&\; mod(\mathbf{j},\mathbf{2}) = \mathbf{1} \end{cases} \quad (\mathbf{4})$$

where

I_{HC} - Horizontal chrominance image

R - Red data

B - Blue data

G_{HR} – Horizontal Green image

G_{HB} – Horizontal Blue image

In this manner, the vertical chrominance image I_{VC} is also computed. The horizontal Gradient computation is done using Equation (5).

$$\mathbf{I_{HG}^{i,j}} = \begin{cases} \mathbf{abs} \left(\mathbf{I_{HC}^{i,j}} - \mathbf{I_{HC}^{i,j+2}}\right), & \mathbf{if\ \ j < fix}\left(\frac{\mathbf{W}}{\mathbf{2}}\right) - \mathbf{2} \\ \mathbf{abs} \left(\mathbf{I_{HC}^{i,j}} - \mathbf{I_{HC}^{i,j-2}}\right), & \mathbf{else\ \ i} \in \left[\mathbf{0}, \mathbf{fix}\left(\frac{\mathbf{H}}{\mathbf{2}}\right) - \mathbf{1}\right], \mathbf{j} \in \left[\mathbf{0}, \mathbf{fix}\left(\frac{\mathbf{W}}{\mathbf{2}}\right) - \mathbf{1}\right] \end{cases} \quad (5)$$

where

I_{HG} - Horizontal Gradient Image

In this manner, the vertical Gradient computation image I_{VG} is computed. The horizontal delta I_{HD} values are computed using Equation (6) and Equation (7).

$$W_{5x5}^{p+2,q+2,} = I_{HG}^{i+p,j+q}, p\epsilon[-2,+2], \quad q\epsilon[-2,+2] \quad (6)$$

$$I_{HD}^{i,j} = \sum_{m=0}^{4}\sum_{n=0}^{4} W_{5x5}^{m,n} \quad (7)$$

$$i \in \left[2, \text{fix}\left(\frac{H}{2}\right) - 3\right]$$

$$j \in \left[2, \text{fix}\left(\frac{W}{2}\right) - 3\right]$$

Herein, the $W_{5\ x\ 5}$ speaks about the block size of 5 x 5. Likewise, the vertical delta I_{VD} is computed. In the R and B locations, the delta values of either I_{HD} or I_{VD} decides whether the horizontal-Green is optimum value or the vertical-Green is optimum through the greater value among I_{HD} and I_{VD}. The resultant value is stored in the missing Green locations.

The estimation of R & B values at Green locations are computed using neighbour data. Furthermore, the R values are computed on the Blue locations and the B values are computed on the Red location.

The ESNIU upsampling is applied on this demosaicked color image. The block diagram of ESNIU upsampling is given in Figure 5. At very beginning, the predictor value is filled from the demosaicked image.

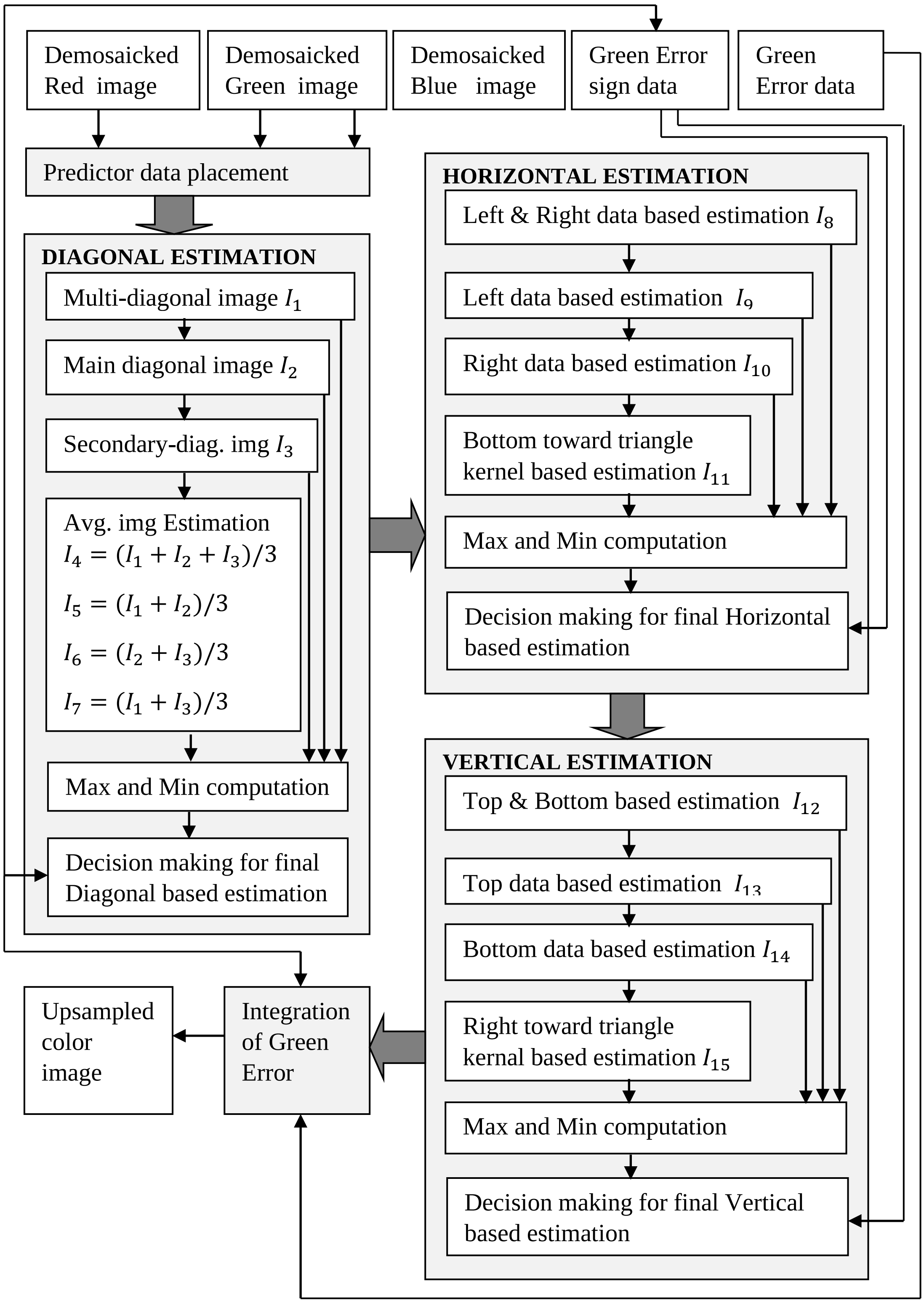


Fig.5: Block diagram of the proposed ESNIU upsampling method.

P	H	P	H	P	H
V	D	V	D	V	D
P	H	P	H	P	H

V	D	V	D	V	D
P	H	P	H	P	H
V	D	V	D	V	D

Fig.6: Location representation for horizontal, vertical and diagonal based interpolations.

The Figure 6 shows the locations refer to the type of interpolation applied for ESNIU upsampling process. The term p refers the predictor value taken from demosaicked image. The term H points-out the locations to be solved by horizontal direction interpolation. The term V refers the locations to be resolved by vertical direction interpolation. The term D focuses the locations to be estimated by diagonal-direction interpolation.

The multi-diagonal interpolation image I_{D1} is obtained using the four neighbour diagonal data with the use of averaging function. The main diagonal interpolated image I_{D2} is obtained using the two neighbours of Left-top and Right-bottom with the help of averaging process. The secondary diagonal interpolated image I_{D3} is obtained using the two neighbours of Right-top and Left-bottom using the averaging process. From these, three images additional images are generate using equations ranging from Equation (8) to Equation (11).

$$I_{D4} = \frac{I_{D1} + I_{D2} + I_{D3}}{3} \quad (8)$$

$$I_{D5} = \frac{I_{D1} + I_{D2}}{2} \quad (9)$$

$$I_{D6} = \frac{I_{D2} + I_{D3}}{2} \quad (10)$$

$$I_{D7} = \frac{I_{D1} + I_{D3}}{2} \quad (11)$$

The maximum value MX among the I_{D1} to I_{D7} images is computed. The minimum value MN among the I_{D1} to I_{D7} images is computed. The Equation (12) decides, which is the final estimated of diagonal based estimation for locations spotted by the term 'D' in Figure 6.

$$I_U^{i,j} = \begin{cases} MX, & \text{if } I_{SGN}^{i,j} = 1 \\ MN, & \text{else} \end{cases} \quad (12)$$

i ϵ [1, H-1, step2], j ϵ [1, W-1, step2]

where

I_{SGN}- Green Error Sign Image

I_U - Upsampled Image

The multi-valued horizontal interpolated image I_{H1} is obtained using the left and right element. The Left-valued horizontal interpolated image I_{H2} is obtained using the left side element. The Right-valued horizontal interpolation image I_{H3} is achieved using the right side neighbour. Additionally, the bottom-element which is already found by the diagonal process, is utilized with the left and right elements to form a triangle based kernel, for the generation of the averaged image I_{H4}. Then the max value and minimum value are found using Equation (13) and Equation (14).

$$M_1 = \max\left(I_{H1}^{i,j}, \quad I_{H2}^{i,j}, \quad I_{H3}^{i,j}, \quad I_{H4}^{i,j}\right) \quad (13)$$

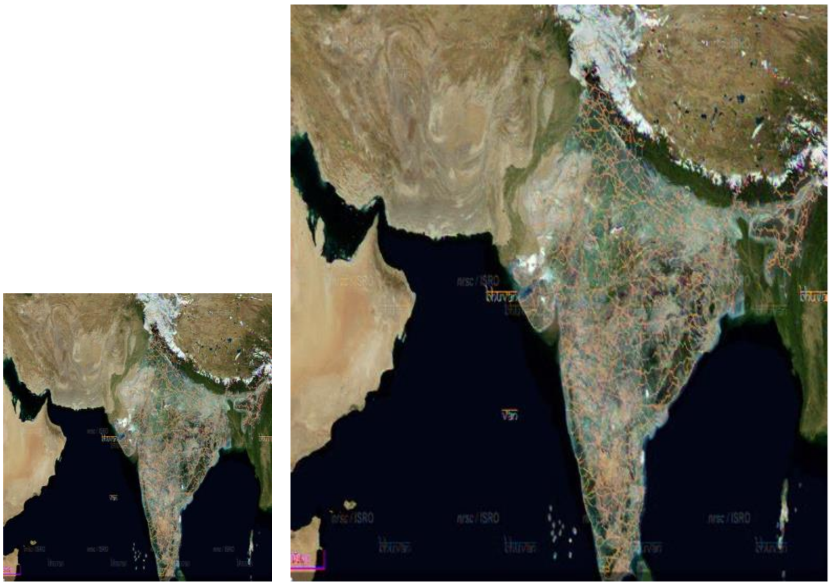
$$M_2 = \max\left(I_{H1}^{i-j},\quad I_{H2}^{i-j},\quad I_{H3}^{i-j},\quad I_{H4}^{i-j}\right) \tag{14}$$

Herein, M_1 means max value and M_2 means min value. The final horizontal upsampled image is generated using Equation (15).

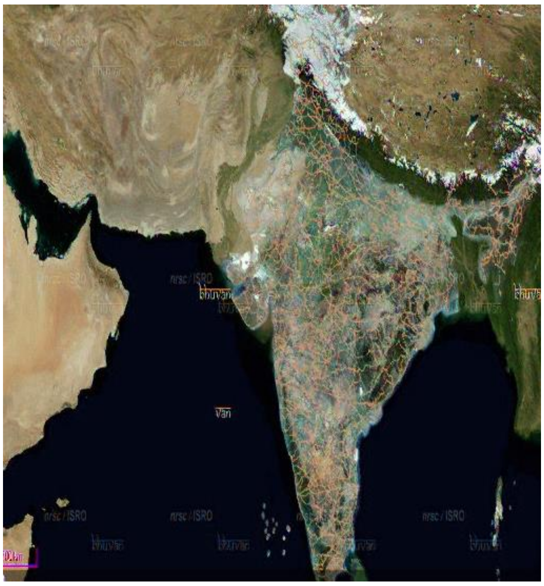
$$I_U^{i,j} = \begin{cases} M1, & \text{if } I_{SGN}^{i,j} = 1 \\ M2, & \text{otherwise} \end{cases} \tag{15}$$

$i \in [0, H\text{-}1, \text{step}2]$, $j \in [1, W\text{-}1, \text{step}2]$

The multi-valued vertical interpolated image I_{V1} is obtained using the Top and bottom neighbours. The Top valued vertical interpolated image I_{V2} is attained via the top-element. The bottom-valued vertical interpolation image I_{V3} is found using the bottom side neighbour. Furthermore, the right-element which is already found by the diagonal process, is handled with the top and bottom neighbours to form a triangle based kernel, for the generation of the averaged image I_{V4}. Then the maxvalue and minimum value are found similar with Equation (13) and Equation (14). The final vertical upsampled image is generated similar with Equation (15). The Green-Error and Green-error-sign data are used to attach the error info with the final upsampled color image. In this way the final decompressed image is reconstructed using the MGD demosaicking and ESNIU upsampling process.



(a) (b)



(c)

Fig.7: Sample outputs of decompression section of the proposed ESNIU-MGD method for Sat_img1: a) Demosaicked color image by MGD method, b) ESNIU based upsampling c) Final decompressed image after the Green error integration.

The Figure 7 illustrates the outputs of the decompression section of the proposed method.

III Experimental results and discussion

The proposed method is compared and analyzed against the following two lossy compression methods:

- DCT based difference lookup table oriented Lossy mode image compression (DCT-DLT) [28]
- Just noticeable difference based perceptual optimization oriented Lossy image compression (JNDPO) [29]

The proposed method is tested by two image databases and they are:

- ISRO database
- HASSELBLAD database.

The ISRO database consists of the Satellite images [26]. The HASSELBLAD database is created to set to the natural images [27].

Peak signal to Noise Ratio is an analytic measure to show the quality of compressed image. It can be computed using Equation 16.

$PSNR = 10 * log10\ (\ 255^2/MSE\ )$ (16)

Herein, the Mean Square Error (MSE) is computed using the uncompressed-image and the reconstructed image. The higher PSNR refers the better compression technique.

Table 1: PSNR analysis for ISRO database

Database name	Image name	PSNR (db)		
		DCT-DLT method	JND-PO method	ESNIU-MGD method
ISRO database	ISRO_1	24.81	25.88	28.26
	ISRO _2	24.07	25.33	27.40
	ISRO _3	25.33	26.40	28.47
	ISRO _4	23.00	24.26	26.39
	ISRO _5	25.86	27.29	29.79

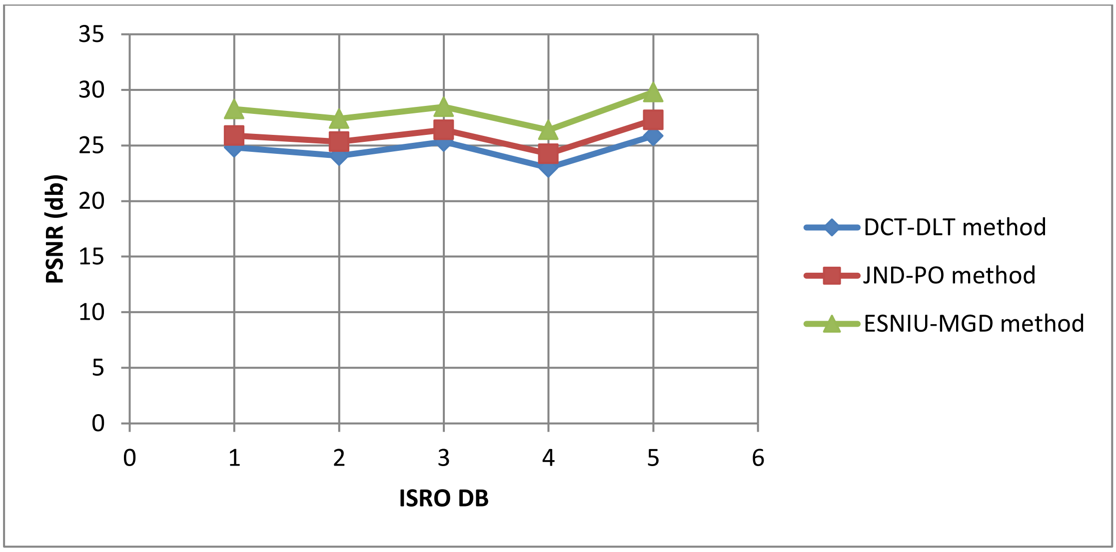


Fig.8: PSNR analysis chart for ISRO database images.

The Table 1 and Figure 8 focus the PSNR analysis of the ISRO dataset. The average PSNR obtained by proposed method is 27.46 db. The proposed method achieves higher PSNR than the existing methods for the ISRO database.

Table 2: PSNR analysis for HASSELBLAD database

Database name	Image name	PSNR (db)		
		DCT-DLT method	JND-PO method	ESNIU-MGD method
HASSELBLAD database	HASSELBLAD _1	22.55	23.19	25.59
	HASSELBLAD _2	23.64	24.26	26.69

	HASSELBLAD _3	25.69	25.92	28.56
	HASSELBLAD _4	24.56	25.16	27.21
	HASSELBLAD _5	22.42	23.03	25.05

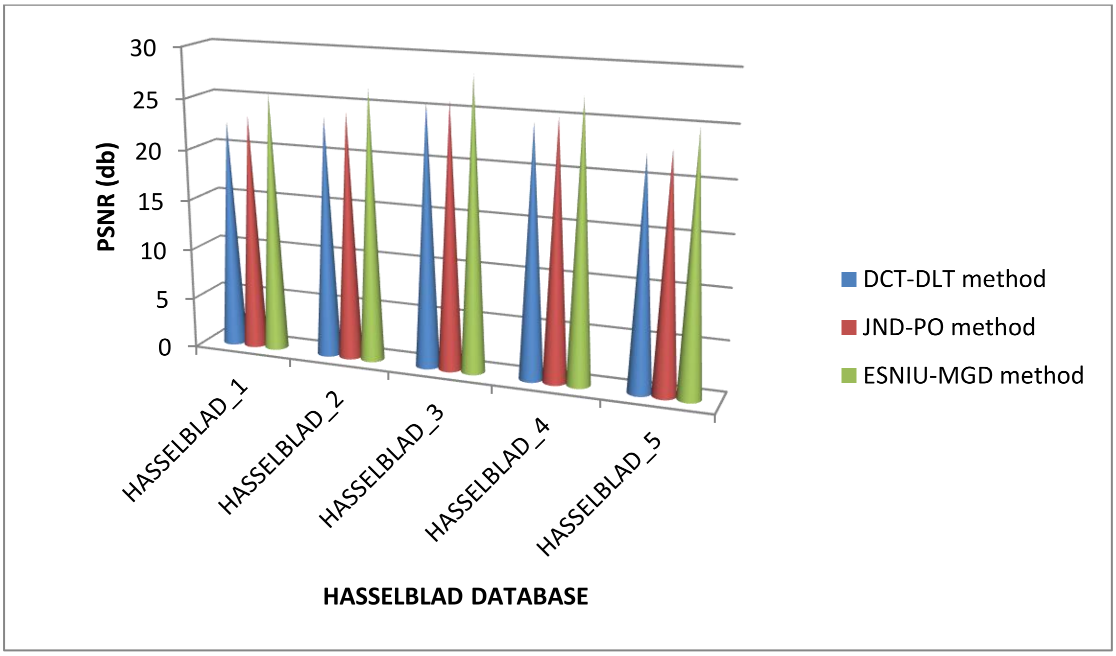


Fig.9: PSNR analysis chart for HASSELBLAD database images.

The Table 2 and Figure 9 point out the PSNR analysis of the HASSELBLAD dataset. The maximum PSNR obtained by proposed method is 26.62 db. The proposed method achieves higher PSNR than the existing methods for the HASSELBLAD database.

The compression ratio (CR) is the measure of compression which is the ratio between the uncompressed image size and the compressed image size. It can be computed using Equation 17.

$$CR=\frac{\text{uncompressed image size}}{\text{compressed image size}} \quad (17)$$

Table 3: Compression ratio analysis for ISRO database

Database name	**Image name**	**CR**		
		DCT-DLT method	**JND-PO method**	**ESNIU-MGD method**
ISRO database	ISRO _1	8.41	8.95	12.17
	ISRO _2	8.07	8.61	11.80
	ISRO _3	7.38	8.00	11.61

	ISRO _4	9.23	9.79	12.69
	ISRO _5	8.53	9.11	12.31

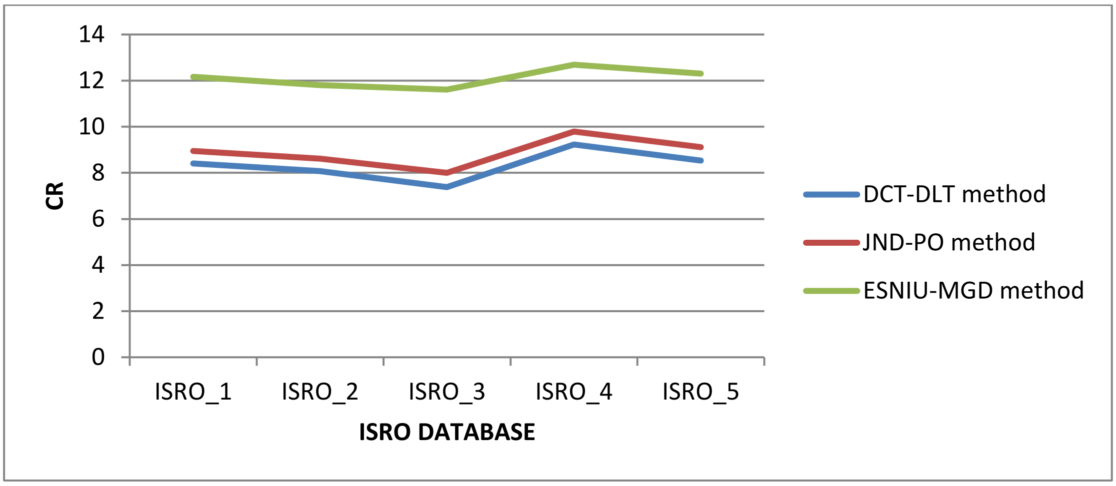


Fig.10: CR analysis chart for ISRO database images.

Herein, the higher CR means better compression technique. The Table 3 and Figure 10 express the CR analysis of the ISRO dataset. The maximum CR obtained by the proposed method is 12.11. The proposed method achieves higher CR than the existing methods for the ISRO database. The higher CR prolongs the lifetime of the network communication [34][35].

Table 4: CR analysis for HASSELBLAD database

Database name	**Image name**	**CR**		
		DCT-DLT method	**JND-PO method**	**ESNIU-MGD method**
HASSELBLAD database	HASSELBLAD _1	7.26	7.96	11.97
	HASSELBLAD _2	9.15	9.62	12.41
	HASSELBLAD _3	7.61	8.28	11.89
	HASSELBLAD _4	7.91	8.48	12.33
	HASSELBLAD _5	8.27	8.92	12.96

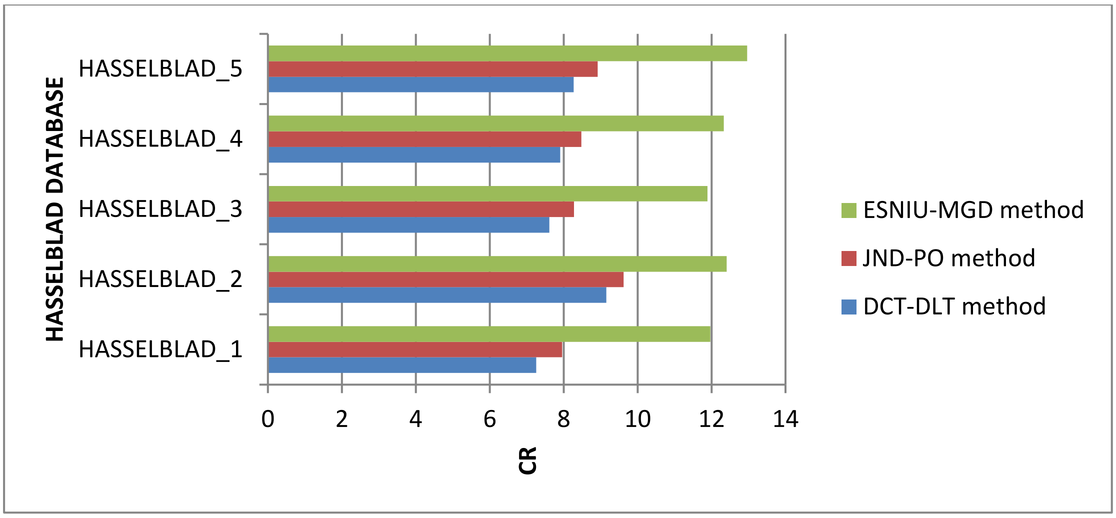


Fig.11: CR analysis chart for HASSELBLAD database images.

The Table 4 and Figure 11 express the CR analysis of the HASSELBLAD dataset. The maximum CR obtained by proposed method is 12.31. The proposed method obtains higher CR than the existing methods for the HASSELBLAD database.

IV Conclusion

This paper speaks about a new lossy image compression method involving the two concepts namely MGD demosaicking and ESNIU upsampling. This method intakes the color RGB image produces the compressed image with better quality. Herein, the ESNIU upsampling is the main contribution of this paper. The ISRO database and HASSELBLAD databases are used for testing the image sets. The average PSNR produced by this approach is 27.04 db. The average CR of the proposed method is 12.21. The proposed method is the highly beneficial method in case of both the analytic metrics like PSNR and CR, than the other existing methods. The proposed method produces successfully the target outputs without any fail. The future work of this method can be the integration of a demosaicking method instead of MGD demosaicking to improve the compression ratio and the PSNR.

References

[1] Image Compression, available from <www.alliedacademies.org>, accessed on [15-Jan-2021].
[2] Lossy Compression, available from <www.geeksforgeeks.org >, accessed on [15-Jan-2021].
[3] Lossy Compression, available from <www.photokonnexion.com>, accessed on [16-Jan-2021].
[4] Lossy Compression, available from <www.en.wikipedia.org>, accessed on [17-Jan-2021]
[5] J. Uthayakumar, T. Vengattaraman, P. Dhavachelvan, "A Survey on data compression techniques: From the Perspective of data quality, Coding Schemes, data type and applications", Journal of King Saud University-Computer and Information Sciences, No 1319-1578,16 May 2018.

[6] Nicos Herodotou and Anastasios N. Venetsanopoulos, "Color image interpolation for high resolution acquisition and display devices", IEEE transactions on consumer electronics, vol. 41, issue 4, pp. 1118-1126, 1995.

[7] Kwan Pyo Hong, Joon Ki Paik, Hyo Ju Kim and Chul Ho Lee,"An edge preserving image interpolation system for a digital camcorder", IEEE transactions on consumer electronics, vol. 42, no. 3, pp. 279-284, 1996.

[8] Neil A. Dodgson ”Quadratic interpolation for image resampling”, IEEE transactions on image processing, vol. 6, no. 9, pp. 1322-1326, sep 1997.

[9] Chulhee Lee, Murrey Eden and Michael Unser, ”High quality image resizing using oblique projection operators”, IEEE transactions on image processing, vol.7, issue 5, pp. 679-692, 1998.

[10] Nathalie Plaziac, ”Image interpolation using neural networks”, IEEE transactions on image processing, vol. 8, issue 11, pp. 1647-1651, Nov. 1999.

[11] Sergio Carrato and Livio Tenze, ”A high quality 2x image interpolator”, IEEE signal processing letters, vol. 7, issue 6, pp. 132-134, 2000.

[12] Xin Li and Michael T.Orchard, ”New edge directed interpolation”, IEEE transactions on image processing, vol. 10, issue 10, pp. 1521-1527, 2001.

[13] Hoon Yoo and Jechang Jeong,”Direction oriented interpolation and its application to de-interlacing”, IEEE transactions on consumer electronics, vol. 48, issue 4, pp. 954-962, 2002.

[14] Jung Woo Hwang and Hwang Soo Lee, ”Adaptive image interpolation based on local gradient features”, IEEE signal processing letters, vol. 11, issue 3, pp. 359-362, March 2004.

[15] Hussein A. Aly and Eric Dubois, ”Image upsampling using total variation regularization with a new observation model”, IEEE transactions on image processing, vol.14, issue 10, pp. 1647-1659, Oct 2005.

[16] Gregory Dillen Benoit Georis, Jean Didier Legot and oliver Cantineau, ”combined line based architecture for the 5-3 and 9-7 wavelet transform of JPEG2000”, IEEE transactions on circuits and systems for video technology, vol. 13, issue 9, pp. 944-950, 2003.

[17] Alfred M.Bruckstein, Michael Elad and Ron Kimmel, ”Down-sampling for better transform compression”, IEEE transcations on image processing, vol. 12, issue 9, pp. 1132-1144, Sep 2003.

[18] Shih-Chung B.Lo, Huai Li and Mathew T.Freedman, ”optimization of wavelet decomposition for image compression and features preservation”, IEEE transcations on medical imaging, vol. 22, issue 9, pp. 1141-1151, Sep 2003.

[19] Shantanu D.Rane, Guillermo Sapiro, and Marcelo Bertalmio, ”Structure and texture filling-in of missing image blocks in wireless transmission and compression applications”, IEEE transactions on image processing, vol. 12, issue 3, pp. 296-303, March 2003.

[20] Peter Schelkens, Adrian Munteana, Joeri Barbarien, Mihnea Galca, Xavier Giro-Nieto and Jan Cornelis, ”Wavelet coding of volumetric medical datasets”, IEEE transactions on medical imaging, vol. 22, issue 3, pp. 441-458, March 2003.

[21] Shaou Gang Miaou and shih-Tse Chen,”Automatic quality control for wavelet based compression of volumetric medical images using distortion constrained adaptive vector quantization”, IEEE transactions on medical imaging, vol. 23, issue 11, pp. 1417-1429, 2004.

[22]. Annabella Gouze, Marc Antonini, Michel Barlaud and Benoit Macq, ”Design of signal adapted multi-dimentional lifting scheme for lossy coding”, Image transactions on image processing, vol. 13, issue 12, pp. 1589-1603, Dec 2004.

[23] Ali Moghaddamjo Reza and Lian Zhu,"Analysis of error in the fixed point implementation of two dimensional discrete wavelet transforms", IEEE transactions on circuits and systems-I regular papers, vol. 52, issue 3, pp. 641-655, 2005.

[24] Mark A. Robertson and Robert L. Stevenson, "DCT quantization noise in compression images",IEEE transactions on circuits and systems for video technology, vol. 15, issue 1, pp. 27-38, Jan 2005.

[25] Damon M.Chandler and Sheila S.Hemami,"Dynamic contrast based quantization for lossy wavelet image compression", IEEE Transaction on image processing, vol. 14, issue 4, pp. 397-410, 2005.

[26] ISRO database, Accessed from <https://bhuvan.nrsc.gov.in/bhuvan_links.php>

[27] HASSELBLAD database, Accessed from < https://www.hasselblad.com/>

[28] A. Messaoudi and K. Srairi, " New colour image compression algorithm based on the DCT transform using difference lookup table", IET Electronics letters, vol. 52, no. 20, pp. 1685 - 1686, 2016.

[29] Xinfeng Zhang, Shiqi Wang, Ke Gu, Weisi Lin, Siwei Ma and Wen Gao, "Just-Noticeable Difference-Based Perceptual Optimization for JPEG Compression", IEEE signal processing letters, vol. 24, no. 1, pp. 96-100, 2017.

[30] Ibrahim Pekkucuksen and Yucel Altunbasak," Multiscale Gradients-Based ColorFilter Array Interpolation", IEEE transactions on image processing, vol. 22, no. 1, pp. 157-195, 2013.

[31] Ezhilarasi M. & Krishnaveni V.,"An evolutionary multipath energy-efficient routing protocol (EMEER) for network lifetime enhancement in wireless sensor networks", Soft Computing", vol. 23, issue 18, pp. 8367-8377, 2019.

[32] M. Ezhilarasi. and V. Krishnaveni, "A survey on wireless sensor network: energy and lifetime perspective", Taga Journal of Graphic Technology, vol. 14, 2018.

[33] M. Ezhilarasi and V. Krishnaveni, "International Journal of Networking and Virtual Organisations", vol, 23, issue 4, pp. 312-326, https://doi.org/ 10.1504/IJNVO.2020.110502, 2020.

[34] Nagarajan Munusamy, "A New Approach to Improve Life Time Using Energy Based Routing in Wireless Sensor Network", International Journal of Science and Research (IJSR).

[35] Nagarajan Munusamy and S. Karthikeyan, "A new approach to increase the life time and efficiency of wireless sensor network", International Conference on Pattern Recognition, Informatics and Medical Engineering (PRIME-2012), IEEE, 2012.

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