International Journal of Advances in Image Processing Techniques– IJIPT
Volume 4: Issue 1 [ISSN : 2372-3998]
Publication Date : 06 April, 2017

Efficient Compression of Manuscript Images

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***Abstract*— This paper is primarily focused on our contribution aimed towards the compression of old Marathi Manuscript images. Our method of compression is working on the separation of the foreground from background, and then compressing it individually. Since foreground contains most intelligence of the manuscript image, we may compress it losslessly to preserve all of its aspects. Generally background of the manuscript have varying color gradient which carries no important information and therefore less significant. Hence we may compress background with lossy compression method. We carried over experimentation on 8 different test images under study. DWT based lossy coding is used for background compression and CALIC based lossless coding for foreground compression which obtains relatively optimized compression individually and when applied together achieved even higher level of compression. This hybrid approach combining DWT and CALIC together is proposed to achieve the improved compression at acceptable quality of the reconstructed manuscript images.**

Keywords—Image processing, Compound image, Multilayer compression.

I. Introduction

We are now in era of digitization. Therefore it requires providing large storage to store scanned documents in computers and which should be made available on internet as and when required. The accessing scheme should be very much effective. To meet the goal, there is need to search for suitable compression strategies to deal such documents while storing. For digitization aspect, it requires to scan the documents and then to store. it. To meet the requirements of related services, Document image processing therefore emerging as important research field. The document image in general has 3 individual components such as text part, graphics part (if present) and pictures (if involved). These types of images are commonly found in magazines, brochures, web-sites etc. In our research, we studied the same kind of images in manuscript book under study. The illuminated cover page of the book is specially considered for such type of document image to which we aim to apply suitable compression strategy. As there is a combination of two different image classes like text/graphics and pictures, their compression methodology can be logically thought of combining multiple compression schemes and region segmentation [1, 2].

As our study is only considering the old manuscript images, we have great concern of preservation than to achieve only highest possible compression sacrificing its originality and visual quality. Here we are focused to attend the largest compression, at which we can offer both, a very good visual quality and preservation of the manuscript image. The traditional compression schemes are generally suits to a particular image type and found application specific. It is really challenging to compress these types of documents with such type of traditional approach. Textual and natural images need different resolutions [3]. Text image requires low value of tonal resolution but should have sufficient value of spatial resolution which helps to preserve the features [4, 5]. Visual details such as font, color and texture are important in the historically important documents and handwritten text [6]. Preservation of the edges and shapes of the characters is really carrying importance while compressing text part associated with line art [7]. Segmentation strategy may be decided on the basis of different regions and different algorithms may be applied to different and distinguishable regions of the document image. An important stage is to form the imaging model for document compression system. This involves separating the image into separable regions or classes of interest and then compressing each individual region/class accordingly. It follows spatial type of segmentation through which each decompressed region can be fitted into the reconstructed document image concurrently.

The other option is to resolve the image in its multiple image layers. The individual image layer can be separately compressed and then finally fitted all the layers into one. The imaging model of Mixed Raster Content abbreviated as MRC is characterized by such multi-layer and multi-resolution scheme which is found suitable to compress the compound document. MRC compression starts with the layer segmentation algorithm. It considers three different image layer which includes Foreground layer (FG), Background layer (BG) and a layer of binary Mask. All three layers in proper coordination are able to reconstruct and hence recover the final image at the receiver. The foreground is then poured through the layer of binary mask onto the background to finally reconstruct the image. [8, 9].In short, the original document image is to be segmented into layers; each individual layer can then be considered for independent compression using different algorithms. The paper discuss the importance of data compression schemes with brief information on multilayer segmentation as the basic of compound image compression and then it is focused on the transform based widely used techniques like DCT, DWT and commanding technique such as CALIC. Further it throws light on compression metrics and lastly paper is concluded with the

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results of experimentation using techniques discussed above, implemented on old Marathi manuscript test images.

II. Data Compression

India has huge number of valuable manuscripts available in various languages that can benefit the mankind. Due to the non availability of the OCR software, it is not possible to go for digitizing the valuable manuscripts. Scanning the manuscript and storing it as images is the only possible solution left to us. The compressed images, if made available, can be shared across the network easily. Manuscripts are scanned usually at high resolution so that the information can be correctly captured. Naturally it causes to increase the pixel count and ultimately the file size. It requires large storage. The good compression scheme is therefore needed with reduced file size. Increased image file size at high resolution can be compressed to manage storage and bandwidth limitation. The aim of data compression lies in reproducing the images with best fidelity and represented with the less number of bits. The compression is generally achieved by removing the redundancy in the image. Removing the redundancy and irrelevancy will not affect the quality of the image significantly. In high resolution images, the component those having high frequency, preserves the details. But these can be removed without image quality degradation. The three layers, representing the compound document, when individually compressed results in a compact and high quality representation. Decomposition scheme introduces redundancy and the redundant layers are easy to compress individually. This simple model becomes extremely powerful for compressing compound documents [9]. Scanned document images falls under another class/category under the classification of compound document images. Their compression strategy has been discussed intensively throughout several past years. Generally a scanned image is segmented in different classes before compression. Most often, the algorithms working on Layer basis and block basis are generally used. Layer based algorithms uses 3 layer basis implemented in mixed raster content (MRC) scheme while DjVu uses a wavelet based coder for the background and foreground, and the mask uses JB2 [10]. Compound document is assumed here as raster document consisting different parts such as text, line/art and picture. But the variety of compression algorithms is usually developed to suit a particular image type, characteristic and application. No single algorithm can be selected as a best candidate suitable for all categories of images and applications. In addition to it, to compress text and line-art, preserving the edges and shapes of characters accurately for better readability is mainly important [11]. Three layers based framework used for document image compression standard named Mixed Raster Content (MRC) is defined in the ITU-T T.44. It preserves text details at reduced bit rate. In MRC encoding, the most important is its segmentation step generating the binary mask. The binary mask separates out the text and line-graphics from background of the document. The traditional approach for document binarization is Otsu's method. It thresholds pixels divides the document's histogram and separates out foreground from the background. However, many statistical based approaches are recently developed [12]. The binarized text compression becomes typically lossless. The case is different for continuous tone image due to the availability of various patterns and the frequency components. It is easy to mask high valued frequency components using lossy compression. It is observed that text part requires higher resolution than pictures.

III. Discrete Cosine Trasform

The Discrete Cosine Transform (DCT) decorrelates the image data. Thereafter each of the transform coefficients is encoded separately with no loss in compression efficiency. The DCT transforms the signal in the spatial domain to a frequency domain. It is the summation of sinusoids which varies in magnitude and frequencies. DCT concentrates its most of significant information in just few coefficients. These coefficients are then normalized as per the quantization table. Quantization mainly affects the entropy level and the compression ratio. Quantization value is inversely related with the reconstructed image quality, better MSE and the better compression ratio [13]. In the lossy compression schemes, the less significant frequency components are removed during quantization, and the most important frequency components are then used to retrieve the image. After quantization, the coefficients obtained are arranged in a zigzag fashion for further compressing it by an efficient lossy coding technique. The DCT mainly offers following advantages:

(1) It can pack almost all of the important information in only few numbers of coefficients.

(2) It reduces the blocking artifact which results from boundaries of the sub-images [14].

For the lower compression ratio, the distortion is not usually observed by human visual system. Blocking artifacts are resulted from the heavy compression. It appears as large pixel blocks. For such higher value of compression, the visible blocking artifacts across the block boundaries cannot be neglected [15].The false contouring is observed in visibly smooth graded area in an image. It is distorted by a deviation that appears like a contour map for the specific image which has gradually varying shaded areas [16]. The reason behind the false contouring is the over quantization of the transformed coefficients [17].

IV. Discrete Wavelet Transform

Mathematical tool 'Wavelet' changes the coordinate system through which we are able to represent the signal to other best suited domain for achieving compression. Wavelet based coding techniques are found more robust on account of transmission as well as decoding errors. It can be suitably applied to those applications in which scalability and tolerable degradation are allowed [18].Wavelets used to decompose and analyze signals such as images using a hierarchy of increasing resolutions. Wavelets used to produce natural multi resolutions of every image. The low pass channel output is always found usefully compressed. Wavelet utilizes unconditional basis therefore their coefficients reduces rapidly. Due to its adjustability Wavelets can be suitably designed for the individual application. It involves only multiplications and

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additions, the calculations of DWT are most suitable to the digital computation in computers [19]. The multi resolution concept added a new dimension in representing signals. Here, an event is decomposed into its finer details. It can be represented in both, its coarse approximation as well as its finer details. These coarse and finer detail subspaces are orthogonal to each other [20][21]. We get compressed image through first level decomposition. To achieve more compression, we require repeating above steps more times depending on number of decomposition level required [22]. DWT offers benefits such as: It allows image representation on multi resolution basis. It allows progressive transmission and rate scalability. It offers better quality and high level of compression ratio.

V. CALIC

The CALIC standard is context-based, adaptive, lossless image Coding scheme [23][24]. This codec offers higher level of lossless compression for continuous tone images at relatively low space and time complexity of algorithm. CALIC standard uses new efficient techniques for context formation, quantization and modeling. Sequential coding scheme CALIC used to encode and decode the applied image in raster scan fashion. Two previous scanned lines in the prediction and context phase of modeling are used in the coding process. Prediction is the initial step of CALIC scheme. It has GAP Gradient- Adjusted Prediction compression algorithm which utilizes prior knowledge of image smoothness. The simple, adaptive, nonlinear predictor GAP adapts to the new intensity gradient level close to the level of a predicted pixel. It calculates the neighboring pixels of current sample as per the estimated intensity gradient level of the image. Represent the current pixel as I[i, j]. Prediction and modeling causal template is illustrated in Figure 1 Represent the adjacent samples using the equations 1. The locations of these pixels are shown in Figure 1.

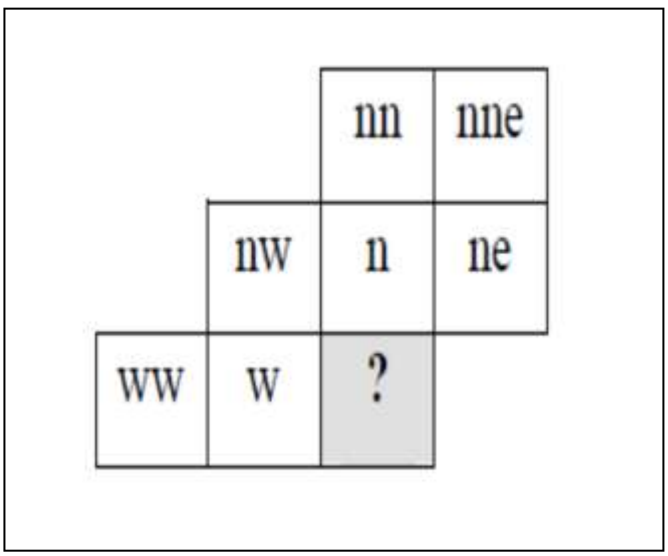

Figure 1. Causal template in prediction and modeling

$$
\begin{aligned}
I_n &= I[i, j-1] \\
I_w &= I[i-1, j] \\
I_{ne} &= I[i+1, j-1] \\
I_{nw} &= I[i-1, j-1] \\
I_{nn} &= I[i, j-2] \\
I_{ww} &= I[i-2, j] \\
I_{nne} &= I[i+1, j-2]
\end{aligned} \tag{1}
$$

The intensity function gradient is estimated in a following manner:

$$d_v = |I_w - I_{nw}| + |I_n - I_{nn}| + |I_{ne} - I_{nne}| \tag{2}$$

Clearly, in the horizontal and vertical directions, d_h and d_v are the estimation of the intensity near the current pixel represented by I[i, j] The Values d_h and d_v used to detects magnitude and orientation of the edges found in the input image. Here d_h represents the horizontal while the d_v represents the vertical gradient. GAP predictor uses values of gradients by following principle. If value of d_v found larger than d_h by some threshold value (typically 80), then there exists horizontal edge, therefore predictor value Iˆ[i, j] for current pixel equals value of left pixel $I_w = I[i-1, j]$ Similarly, if value of d_h larger than value of d_v on 80, then prediction value Iˆ[i, j] equals value of upper pixel $I_n = I[i, j-1]$Otherwise, following linear predictor gives the prediction value:

$$\hat{I}[i, j] = \frac{I_n + I_w}{2} + \frac{I_{ne} - I_{nw}}{4} \tag{3}$$

Contexts for error modeling in CALIC are formed using 144 texture contexts which are then formed into four energy contexts raises to 576 compound contexts. Quantizing the local neighborhood of the pixel forms the Texture contexts:

$$
\begin{aligned}
C &= \{x_0, x_1, x_2, x_3, x_4, x_5, x_6, x_7\} \\
&= \{I_n, I_w, I_{nw}, I_{ne}, I_{nn}, I_{ww}, 2I_n - I_{nn}, 2I_w - I_{ww}\}
\end{aligned} \tag{4}
$$

Then after quantizing the vector C, it forms an 8-bit binary number $B=b_7b_6\ldots b_0$ with the help of prediction value $\hat{I}$ [i, j] used as the threshold:

$$b_k = \begin{cases} 0, if\, x_{k \geq \hat{I}[i,j]} \\ 1, if\, x_{k < \hat{I}[i,j]} \end{cases} 0 \leq k < K = 8 \tag{5}$$

Now B is able to represent the texture pattern in the modeling context and prediction error behavior is indicated by:

$$e = I[i, j] - \hat{I}[i, j] \tag{6}$$

It is not required that an event x_i is a neighboring pixel to I[i, j] in current context. It may be the function of some adjacent pixels also. X_6 and X_7 relates the events that the predicted value of $\hat{I}$ [i, j] forms concave waveform Compound modeling context is resulted after combining the texture contexts with quantized error energy. The contexts of error energy are obtained by using error estimator as below:

$$\Delta = d_h + d_v + 2\,|e_w| \qquad (7)$$

Where $e_w = I[i-1,j] - \hat{I}[i-1,j$. The Value of e_w is chosen in absolute to avoid large errors that can occur consecutively. Estimator Δ is quantized first to four levels resulted to a quantized error energy context Q(Δ).Then after combining with the quantized texture pattern $0 \leq B < 2^K$, it forms compound modeling context, denoted as $C(\delta, \beta)$. Here we have 4 x 2^8 =1024 compound contexts. However, not all 2^8 binary codeword for the B quantizer defined by (5) are possible, available only 144, so the total valid compound contexts are only 4 x 144 = 576. Coding step started by coding of error energy estimator Δ as defined in (7). CALIC offers less bit rate compared to Universal Context Modeling scheme UCM. The context formation, quantization, modeling is to be carefully decided to meet the goal. CALIC was proposed as the lossless compression algorithm for the international standard referred for continuous tone images to ISO/JPEG [25], [26]. CALIC offer the lowest lossless bit rates to six image classes and exhibits the third lowest bit rate for computer generated image class.

VI. Results and Discussion

In this section, the basic parameters of compression measurements are discussed in brief and thereafter experimentation results are discussed. The experimentation steps are indicated in the algorithmic flow shown in figure 2.Experimentation results are tabulated in table1.

A. *Compression Ratio*

By reducing storage requirements and transmission time, data compression provides major saving in cost associated with sending less data over the communication channels. In Addition, compression reduces erroneous bits transmitted, reduces transmission time. It increases the equipment efficiency and also the level of security useful for cryptology. It gives protection in case of unauthorized intrusions in communication systems by providing privacy and authentication. There are few characteristics to judge the performance of image compression algorithms. The extent of storage space reduction achieved is measured in terms of compression ratio. Image quality can be observed through the closeness of the resultant decompressed image with the original one. Compression speed and cost is related to the encoding and decoding computational complexity of the image. These parameters in general are used to decide the suitability of any compression technique for specific application. The decision is normally taken after viewing acceptable reconstructions quality, range of compression ratios, and its implementation costs. Data compression process represents the same amount of information with the reduced file size. The compression ratio(C R) is therefore the ratio of the compressed image size to the original image size.

C R= Size of original image / Size of compressed image

This ratio is always related to the quality of the image. Heavily compressed images are generally found with poor visual

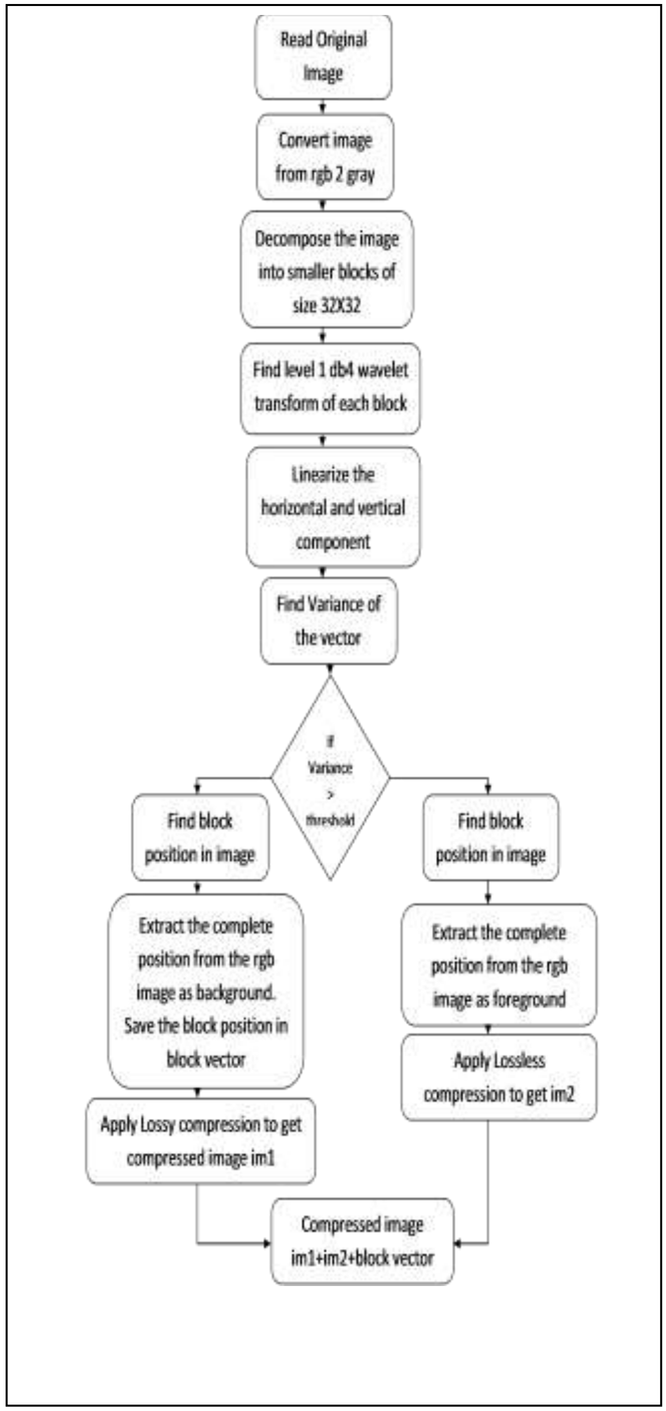

Figure 2. Agorithmic flow graph

quality. Always the balance of compression ratio with that of accepted reconstructed image quality is considered primarily while implementing it for any application. The quality of the image is most important aspect of any compression system. Usually the reconstructed images quality might be degraded during the compression as well as decompression process. Image fidelity measures can assess the

TABLE 1

Type	Lossless Methods			Proposed Method
Image	*Huffman Predictive*	*Arithmetic Predictive*	*CALIC*	*(DWT+ CALIC)*
Test 1	1.5946	1.7608	1.9509	2.9011
Test 2	1.5334	1.6478	1.8309	2.4971
Test 3	1.5908	1.7476	1.9502	2.9101
Test 4	1.5232	1.6252	1.8295	2.4625
Test 5	1.5926	1.7527	1.9567	2.9471
Test 6	1.5212	1.6255	1.8284	2.5201
Test 7	1.665	1.8804	2.0527	3.0783
Test 8	1.6364	1.8517	2.0087	3.1223
Average	1.5822	1.7365	1.926	2.8048

degree of degradation. The distortion measures should be easy to compute and adaptable to the human vision system.Subjective image quality can be determined by statistically processing the fidelity rating can be given by a group of viewers. While the measurement for objective image quality can be done through a computational process. Objective quality can be measured by Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR).

B. *Mean Square Error*

The Mean Square Error is cumulatively calculated as squared error measured from the original image and its compressed version. The lower value of MSE indicates lower error and better quality. It is inversely related with PSNR [27]. The average of the squares of the error is termed as MSE. RMSE is calculated as the square root of MSE [28]. MSE can be calculated as follows:

$$\mathrm{MSE} = \frac{1}{N \times N} \sum_{i=1}^{N} \sum_{j=1}^{N} [I(X,Y) - \acute{I}\ (X,Y)]^2 \qquad (8)$$

Where, I(x, y) represents the original image and the reconstructed image is represented by I'(x, y). The m, n are the dimensions of the image. MSE strongly depends on the intensity scaling of the image.

C. *Peak Signal to Noise Ratio*

The peak error is measured through the measurements of PSNR. PSNR has very wide dynamic range of the signals and therefore the PSNR is always expressed in decibel scale (dB). It is the peak value obtained for the ratio between the signal strength with the noise strength present in a system [29]. Here, a signal refers the given original image and noise refers the error occurred in reconstruction. Therefore it can be seen as the ratio measured between the maximum possible strength of power of a signal to the maximum power of the corrupting noise [30]. The Peak Signal to Noise Ratio is defined as

$$\mathrm{PSNR} = \frac{10 \log_{10} S^2}{\mathrm{MSE}} \qquad (9)$$

Here, S refers the maximum intensity value. PSNR is computed by measuring the pixel difference calculated between the original image and compressed image. PSNR decreases with the increase in compression ratio for the image. Here, the experimentation results of compression are enlisted in Table 1. The figure 8 shows the comparison on the basis of compression performance obtained after implementing different schemes. Tabular results prove that the proposed DWT+ CALIC. Preprocessing of manuscript images involves generally quality enhancement through noise removal. Keeping in view of storage and transmission of these types of quality images requires a large memory and hence adversely affects the transmission speed. Here compression schemes now become important to implement on such type of document images. We have used only lossless type of compression schemes to fulfill the aim of preserving all the quality related components of the document. To provide this requirement the various techniques must be operated over specific document images under consideration. The work of compression becomes more challenging when it is dealt with the degraded manuscript images. To study comparatively, we carried out experimentation with the different recent and most popular lossless type of image compression algorithms for degraded Marathi manuscript images. According to the experimentation results, Predictive Huffman coding proves speedy while the CALIC is found best on the basis of compression achieved and bit rate. The compression performance with the three best methods (Predictive arithmetic, Predictive Huffman and CALIC) does not reach 2. Therefore, a topic for further investigation is whether one can extend the limited and selective use of lossy compression methods that could be allowed in part which may improve the compression performance without affecting quality of the Marathi manuscript image under consideration. The paper is focused on the same and through experimentation it is proposed to use an efficient hybrid approach to utilize faster DWT instead of computationally heavy DCT for lossy compression of background part and CALIC is utilized for lossless compression of foreground part together. This proposed hybrid approach significantly improves the compression ratio. Figure 3 shows original manuscript image as one of the test images under study, figure 4 shows the foreground and figure 5 shows background of original manuscript test image figure 6 shows the compressed image.

VII. Conclusion

In search of finding an efficient approach for compressing old Marathi Manuscript images, the experimentations are carried over on 8 different test images under study. It is started from separating the foreground from background, and then compressing it individually. Preprocessing of manuscript images involves generally quality enhancement through noise removal. Keeping in view of storage and transmission of these types of quality images requires a large memory and hence adversely affects the transmission speed. Here compression scheme is now become important to implement on such type of document images. We have used only lossless compression schemes to fulfill the aim of preserving all quality related components of the document. To provide this requirement the

Figure 3. Original test image

Figure 4. Foreground of the original image

Figure 5. Background of original image

Figure 6. Compressed image

various techniques must be operated over specific document images under consideration. The work of compression becomes more challenging when it is dealt with the degraded manuscript images. To study comparatively, The experimentation are carried over with the different recent and most popular lossless image compression algorithms for degraded Marathi manuscript images. According to the experimentation results, Predictive Huffman coding proves speedy while the CALIC is found best on the basis of compression ratio and bit rate both. The compression ratio with the three best methods (Predictive arithmetic, Predictive Huffman and CALIC) does not reach 2. Therefore, a topic for further investigation is whether one can extend the limited and selective use of lossy compression scheme that could be allowed in part to improve the compression performance without affecting visual quality of the Marathi manuscript image under consideration. The paper is focused on the same scope and through experimentation it is proposed to use efficient approach to utilize faster DWT for lossy compression against computationally heavy DCT and CALIC for lossless compression together.

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