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Wavelet Transform Based Image Compression

R.Srinivasa Rao[1], M.Vijay Karthik[2],Saraswathi Nagla[3]
Department of Electronics & Communications Engineering[1], Department of Electrical & Electronics Engineering[2,3], Aurora's Scientific & Technological Institute, Ranga Reddy Dist, Andhra Pradesh-501301, INDIA

ABSTRACT

Image require substantial storage and transmission resources, thus image compression is advantages to reduce these requirements. A good strategy of image compression should assure a good compromise between a high compression rate and a low distortion of the picture. In this paper a lossless digital image compression technique based on Integer Wavelet Transform is proposed. The small deviations in data values are not allowed in certain images for obvious reasons and a potential risk of a person misinterpreting an image. A preprocessing and post processing histogram adjustment is used to prevent overflow/underflow. In proposed technique wavelet transform is applied to entire image, so it produces no blocking artifacts. The results show improved high performances in terms of compression ratio and reconstruction quality.

Index Terms; Digital compression, Integer wavelet transform, Histogram modification.

INTRODUCTION

The fast development of computer applications came with an enormous increase of the use of digital images, mainly in the domain of multimedia, games, satellite transmissions and medical imagery. This implies more the research on effective compression algorithms, the basic idea of the image compression is to reduce the middle number of bits by pixel necessary for image representation. The image compression approaches can be divided in two methods: lossless and loss. Different compression approaches have been studied in the literature[1].

A lossless high-capacity data for image compression based on integer wavelet is proposed. After extracting data embedded, the original image should be reversible from compressed image[2]. The wavelets are excellent approximates and signal analyzers. Their time-frequency analysis makes them an effective and innovative tool.

In this paper, we investigate integer wavelet transform technique for transforming the image. The basic idea behind this technique is to use integer wavelet to transform the data into the different basis. A pre and post histogram is used for A preprocessing and post processing histogram adjustment is used to prevent overflow/underflow.

The paper is organized as follows: Integer wavelet Transform described in section II. Section III represents Histogram adjustment for the preprocessing and post processing of the image compression, section IV gives detailed compression technique, and section V provides the implementation of the proposed technique with results.

II INTEGER WAVELET TRANSFORM

The Wavelet Transform produces floating point coefficients even when applied to integer values. The original integer data can be reconstructed perfectly in theory by using these coefficients. However in practice, we usually use the fixed point format for data values because the fixed point systems are easier to implement[3] [4]. The reduced precession arithmetic used in such systems can introduce round off errors in the computations. In practice traditional wavelet transform have some drawbacks such as it is a floating point algorithm, computer finite word length will bring in rounding error and signals can't be reconstructed exactly, the computation is very complicated, computation cost is very high, it requires more storage space and it is not appropriate to hardware implementation. In order to overcome above drawbacks, this paper uses lifting scheme wavelet - integer wavelet transform[5]. It doesn't depend on Fourier transform, but it still inherits , multi resolution properties of traditional wavelet transform and transforming coefficient, calculation speed is more fast, and it doesn't need extra storage cost so it is called second generation wavelet transform. Hence in applications where we need lossless reconstruction, we need transforms which have reversibility properties even when reduced precision is used. It was shown by calderbank et al., that we can build wavelet transforms that map integers to integers by using lifting structure. The reversibility property is obtained by rounding of the predict filter or update filter output before adding or subtracting in each lifting step. Wavelet filters are decomposed into basic modules by integer wavelet transform, that is, wavelet transform is completed through splitting, predicting and updating, as figure 1 displays.

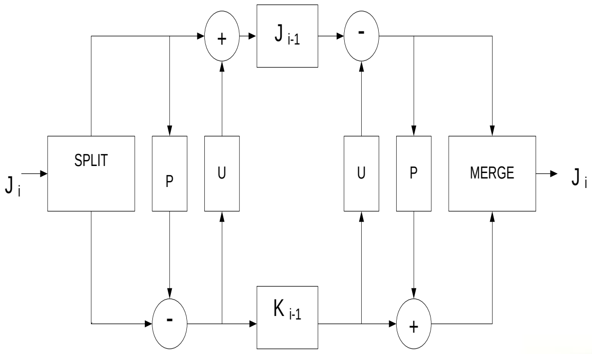


Fig 1. Integer wavelets transform decomposition and Reconstruction diagram

After integer wavelet transform, it has four sub-bands. We will embed the information into three high frequency sub bands. Except that it has advantages of traditional wavelet transform, integer wavelet transform which is applied to digital compression technology has following advantages[6]:

(1) It avoids rounding error of floating point in mathematical transformation;

(2) Its transforming speed is fast and it doesn't need extra storage cost.

III HISTOGRAM ADJUSTMENT

For a given image, after data embedding in some IWT coefficients, it is possible to cause overflow/underflow, which means that after inverse wavelet transform the gray scale values of some pixels in the compressed image may exceed the upper bound (255 for an eight-bit grayscale image) and/or the lower bound (0 for an eight-bit grayscale image). In order to prevent the overflow/underflow, we adopt histogram modification, which narrows the histogram from both sides as shown in. Fig.2. Please refer to [7],[8] for the detailed algorithm. The bookkeeping information will be embedded into the cover media together with the information data.

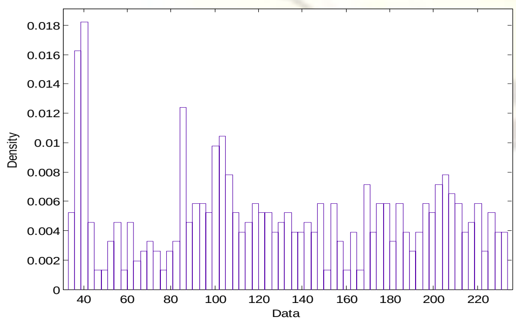


Fig 2(a). Gray scale histogram modification of Original histogram

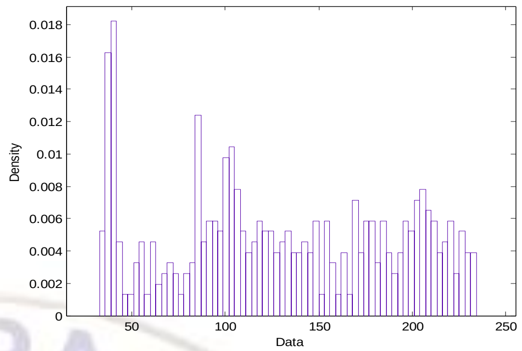


Fig 2(b). Gray scale histogram modification modified histogram

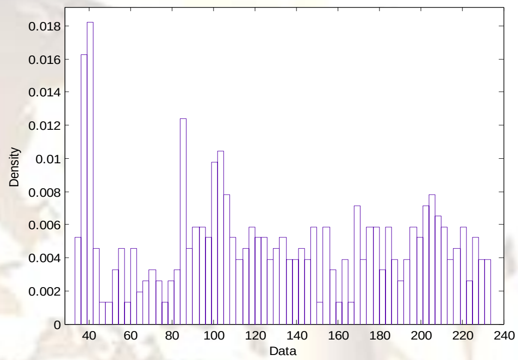


Fig 2(c). Gray scale histogram modification histogram after data embedding.

IV PROPOSED COMPRESSION SCHEME

1. Data Embedding Process:

The main steps of the embedding procedure developed are presented here and summarized.

a. Histogram modification is applied on original image that prevents possible overflow and underflow.

b. We first apply integer wavelet decomposition to the original image. In our experiments, CDF (2, 2) wavelet filters are used to decompose the original gray scale image into one level. After integer wavelet transform, it has four sub-bands.

c. In order to have the compressed image perceptually the same as the original image, we choose to hide data in one (or more than one) "middle" bit-plane(s) in the IDWT domain. To further enhance the visual quality of the compressed image, we embed data only in the middle and high frequency sub bands, specifically in the LH1, HL1 and HH1 sub bands.

d. Construct binary images from 5^{th} bit of LH1, HL1 and HH1 wavelet coefficients. For constructing binary image using LH1, the each integer wavelet coefficients in LH1 is converted into 8 bit binary sequence, if 5^{th} bit of each binary sequence is 1 then assign 2 to binary image otherwise assign 1. For constructing binary image using HL1 and HH1 is same as above.

e. Compress data in binary image obtained from LH1, HL1 and HH1 by using arithmetic coding because of its high coding efficiency.
f. Insert the header information and compressed data together, the embed signal consists of these three. If embedded bit is 1or (0) then convert first integer wavelet coefficient in LH1 sub band into 8 bit binary sequence and replace 1or (0) to the 5^{th} bit plane of that binary sequence and convert back to integer. In this way all the embedded bits hide in "5^{th}" bit-plane in the LH1, HL1 and HH1 coefficients.
g. The way of accessing each wavelet coefficient for embedding depends on secret key.
h. A secret key function that keeps the hidden data secret even after the algorithm is known to public.
i. Take the Inverse integer wavelet transform to reconstruct the compressed image.
j. Perform histogram modification on compressed image.
k. The invisibility of the compressed image.

We use the formula (1) to compare the difference between the original image and the compressed image, Figure 5 demonstrates that the compressed image embedded with the proposed algorithm is invisible, where (a) is the original image, and (b) is the compressed image with compression ratio =91.25.

$$\Upsilon = (1- Tc / To)\ X\ 100 \qquad (1)$$

Where Tc Is Size of Original cover image
To Is Size of Compressed cover image

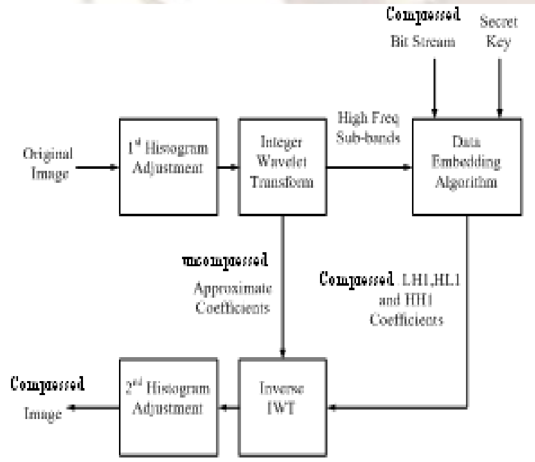


Fig.3 Embedding Method

2. Extraction Process

Extraction of compressed image and inverting of compressed image into original one is reverse process of embedding.

a. Perform histogram modification on compressed image.
b. Perform one level integer wavelet decomposition on compressed image.
c. Extract the embed signal from 5^{th} bit of LH1, HL1 and HH1 wavelet coefficients.

For extracting embed signal with using LH1, the each integer wavelet coefficient in LH1 is converted into 8 bit binary sequence and if 5^{th} bit of each binary sequence is 1, then embed bit is 1 otherwise embed bit is 0.

The sample code given below:

```
Index=1
    for i=1: size (LH1, 1)
    for j=1:size(LH1,2)
    binSeq = dec2bin (abs (LH1(i, j)),8);
    if binSeq (5) == '1'
    embed Signal (index, 1) = 1;
    else
    embed Signal(index,1) = 0;
    end
    index = index + 1;
    end
    end
```

For extracting embedded signal with using HL1 and HH1 same as above.

(a) Based on header information extract binary compressed image from embed signal.
(b) Extract the respective binary images of LH1, HL1 and HH1 from embed signal based on header information.
(c) Decompress to get the original sequence.
(d) Insert the uncompressed 5th bit data back into LH1, HL1 and HH1.
(e) Take the Inverse integer wavelet transform to reconstruct the original image.
(f) Perform histogram adjustment on original image.

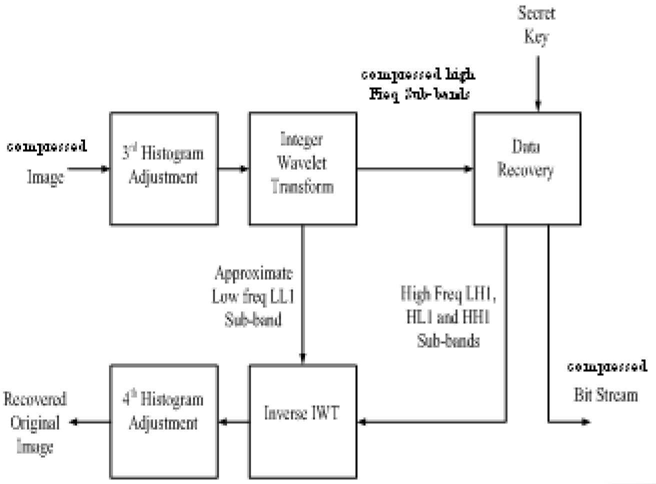


Fig.4 Extraction method

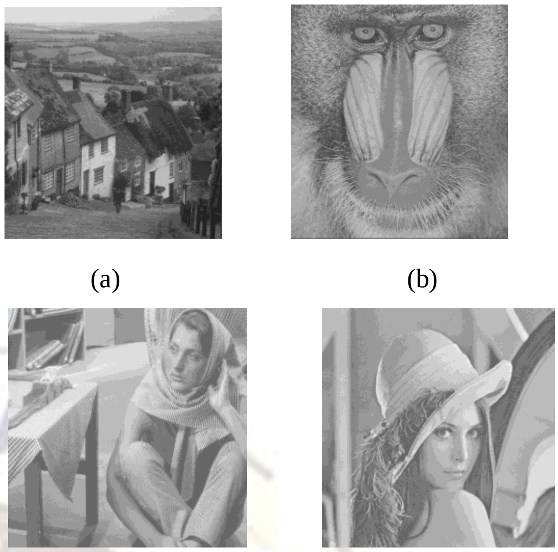
V IMPLEMENTATION

The program code is written in 'MATLAB'. Test images of 'Airplane', 'Lena', 'Baboon', 'Gold hill', and 'Barbara' are used as input images for validation of developed algorithms. The wavelet decomposition of image is done by using CDF (2,2) wavelet filter.

The compressed logo is binary image created and embedded as per algorithm discussed. The embedding is done for the visible compressed logo. The resultant coefficients were inverse transformed to obtain the compressed image. Several test gray scale images of size 512×512 are used in experiments. The original and compressed Airplane images are shown in fig.5. Compression ratio value of Airplane image after compressed embedding is measured as 91.25%. It is observed that imperceptibility requirement is met. The same experiment is conducted on other four images. Fig.6 contains other four compressed images. Table I shows some experimental results.

(a) (b)

Fig.5 Airplane image : (a) Original Airplane image
(b) Compressed image (91.25%)



(a) (b) (c) (d)

Fig.6 Compressed images (a) Compressed Goldhill image (b) Compressed Baboon image (c) Compressed Barbara image (d) Compressed Lena image

Table I The Compression Ratio(%) Value

Host Image 512×512	Compression Ratio value(%)
Lena	81.36
Baboon	89.13
Goldhill	78.57
Airplane	79.23
Barbara	84.56

Table I show that Airplane image has a better embedding capacity than the other images in the experiment. It also shows it has a better visual quality as far as peak signal to noise ratio is concerned.

Table II shows image quality tested for different payloads on the same image using different wavelets. Among various wavelet filters, CDF(2,2) performs better than others for the same payloads. Image quality quickly changes when different wavelets are used.

$$PSNR = \frac{255^2}{\frac{1}{M \times N}\sum_{i=1}^{M}\sum_{j=1}^{N}(H(i,j)-W(i,j))^2} \quad (2)$$

Where $H(i,j)$ Is Original cover image
$W(i,j)$ Is Compressed image

Table II Comparison of performance of various wavelet families on Airplane image for different payload size

Payload bits	cdf(2,2) PSNR (db)	db2 PSNR (db)	Sym4 PSNR (db)	bior3.3 PSNR (db)	bior6.8 PSNR (db)	rbio3.3 PSNR (db)
10000	37.78	35.84	36.37	36.31	36.31	36.24
15129	37.73	35.78	36.25	36.28	36.23	36.29
20164	37.67	35.73	36.26	36.24	36.26	36.16
25281	37.60	35.69	36.11	36.16	36.00	35.99
50176	37.11	35.708	35.89	35.76	35.85	35.58
75076	36.84	35.67	35.90	35.71	36.00	34.67
100489	36.74	**	35.86	35.51	35.05	33.86

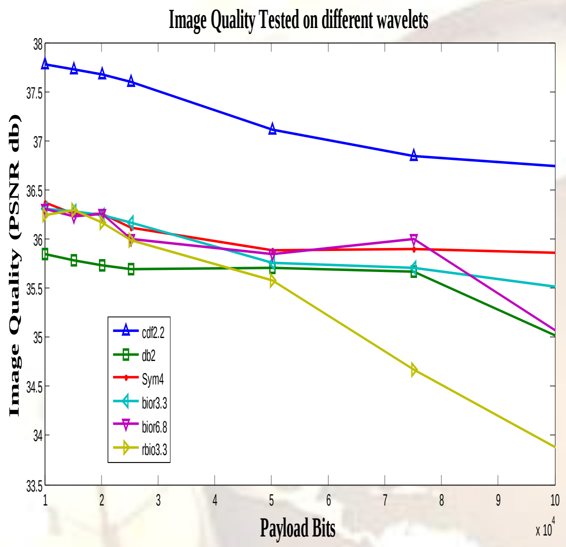


Fig.7 Image Quality Tested on Different Wavelets

Table III shows the comparison between existing methods in literature and proposed method. The proposed method is able to embed up to 196k bits into image of 512 by 512 imperceptibly.

Table III Comparison between existing methods and proposed method

Methods	The amount of data embedded in a 512 × 512 image
Goljan's	3,000-24,000 bits
Guorong	15,000-94,000 bits
Proposed	10000-1,96152 bits

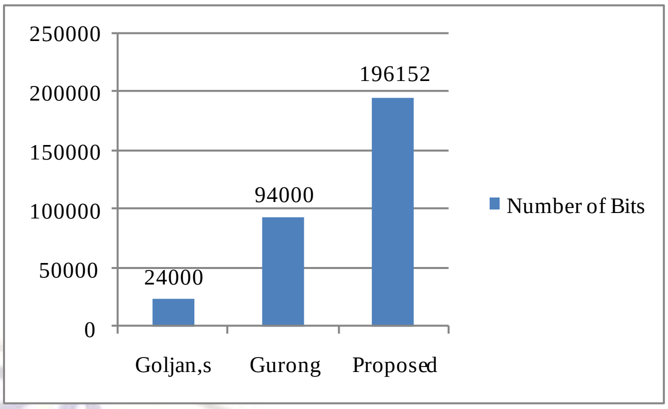


Fig.8 Comparison between proposed and existing methods

CONCLUSION

Simulation experiments on the digital compression of images have been performed using two standard images: Lena and Airplane. In proposed method we verify the compromise that exists between the compression ratio and the quality of the rebuilt image. The proposed image compression algorithm based on integer wavelet transform is able to embed up to 81.36% and 91.25% compression ratio value and into image of 512 by 512 imperceptibly and extracts the embedded data and original image from compressed image without loss of information. The performance of proposed lossless compression algorithm verified by various wavelet filters. Among various wavelet filters, CDF (2,2) performs better than others for the same payloads.

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R. Srinivasa Rao was born in West Godavari, India in 1977. At present he is working as Associate Professor in the Department of Electronics and Communications Engineering, Aurora’s Scientific and Technological Institute, Ranga Reddy Dist -501301, Andhra Pradesh, India. He obtained his M.Tech degree JNTU College of Engineering, JNTU Hyderabad, and Andhra Pradesh, India. He completed Graduation in Engineering, AMIE, The Institution of Engineers (INDIA), Kolkata. His research area includes Signals and Systems, Digital Image Processing and communication systems.

Mamidala Vijay Karthik was born in Hyderabad, India in 1985. At present he is working as Senior Assistant Professor in the Department of Electrical & Electronics Engineering, Aurora’s Scientific and Technological Institute, Ranga Reddy Dist -501301, Andhra Pradesh, India. He obtained his M.E degree from Chaitanya Bharathi Institute of Technology (CBIT) Gandipet, Osmania University, Hyderabad, and Andhra Pradesh, India. He obtained B.Tech degree from Church Institute of Technology, Gagillapur, JNTU Hyderabad, and Andhra Pradesh. His research area includes Wavelets, Power Quality, Power System, and Power Semiconductor Drives.

Saraswathi Nagla was born in Nizamabad, India in 1986. At present she is working as Assistant Professor in the Department of Electrical & Electronics Engineering, Aurora’s Scientific and Technological Institute, Ranga Reddy Dist -501301, Andhra Pradesh, India. She obtained her M.E Degree from Chaitanya Bharathhi Institute of Technology (CBIT) Gandipet, Osmania University, Hyderabad, and Andhra Pradesh, India. She Obtained B-Tech Degree from Srinivasa Reddy Institute of Technology, Munipally, JNTU Hyderabad, Andhra Pradesh. Her research area includes Image Processing, Wavelets, Power Quality, Power System, and Power Semiconductor Drives.