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Efficient Gray Image Compression using Modified JPEG 2000 Standard

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Abstract: The rapid growth of digital imaging applications, including desktop publishing, multimedia, teleconferencing, and high definition television (HDTV) has increased the need for effective and standardized image compression techniques. Lots of techniques are available for the Single channel image compression. i.e. for gray images. For still image compression, the "Joint Photographic Experts Group" or JPEG standard has been established by ISO (International Standards Organization) and IEC (International Electro-Technical Commission). Since then lots of work had been done on single channel image compression mostly based on JPEG compression. But rapid growth in modern communication demands the direct transmission and storage of images with higher compression ratio and less mean square error (RMSE). The available JPEG standard can able to provide smaller root mean square error but not able to generate higher compression ratio. This arises the need of image compression techniques which can able to keep RMSE within an allowable range and simultaneously able to generate higher compression ratio (CR). This paper brought forward a mathematical modification on available JPEG 2000 image compression algorithm so that it can able to provide higher compression efficiency with allowable error rate.

Key words: Single channel image compressions, JPEG 2000 standard, mean square error (MSE), compression ratio (CR).

I. INTRODUCTION

Image compression addresses the problem of reducing the amount of data required to represent a digital image .The underlying basis of the reduction process is the removal of redundant data. From a mathematical viewpoint, this is a process of transforming a 2-D pixel array into a statistically uncorrelated data set .The transformation is applied prior to storage or transmission of the image [1]. Currently image compression is recognized as an "enabling technology". In addition to the areas just mentioned, image compression is the natural technology for handling the increased spatial resolution of today's imaging sensors and evolving broadcast television standards. Furthermore image compression plays a major role in many important and diverse applications, including tele-video-conferencing, remote sensing (the use of satellite imagery for weather and other earth resource applications), document and medical imaging facsimile transmission (FAX) [2],[3], and the control of remotely piloted vehicles in military, space and hazardous waste management applications.

The spatial and spectral redundancies are present because certain spatial and spectral patterns between the pixels and the colour components are common to each other, whereas the psycho-visual redundancy originates from the fact that the human eye is insensitive to certain spatial frequencies. The principle of image compression algorithms are (i) reducing the redundancy in the image data and (or) (ii) producing a reconstructed image from the original image with the introduction of error that is insignificant to the intended applications. The aim here is to obtain an acceptable representation of digital image while preserving the essential information contained in that particular data set.

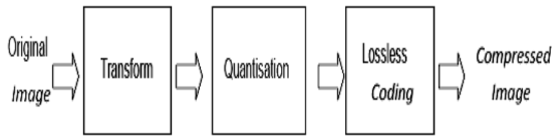

Figure 1: Image compressions System

The problem faced by image compression is very easy to define, as demonstrated in figure 1. First the original digital image is usually transformed into another domain, where it is highly de-correlated by using some transform. This de-correlation concentrates the important image information into a more compact form. The compressor then removes the redundancy in the transformed image and stores it into a compressed file or data stream. In the second stage, the quantization block reduces the accuracy of the transformed output in accordance with some pre-established fidelity criterion. Also this stage reduces the psycho-visual redundancy of the input image. Quantization operation is a reversible process and thus may be omitted when there is a need of error free or lossless compression. In the final stage of the data compression model the symbol coder creates a fixed or variable-length code to represent the quantizer output and maps the output in accordance with the code. Generally a variable-length code is used to represent the mapped and quantized data set. It assigns the shortest code words to the most frequently occurring output values and thus reduces coding redundancy. The operation in fact is a reversible one.

The decompression reverses the compression process to produce the recovered image as shown in figure 2. The

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recovered image may have lost some information due to the compression, and may have an error or distortion compared to the original image.

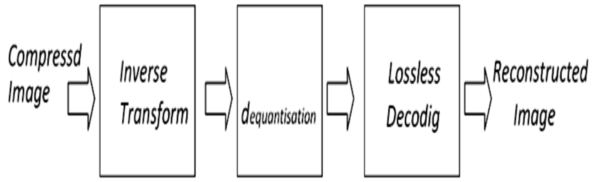

Figure 2: Image decompressions System

II. BASIC ARCHITECTURE OF THE JPEG 2000 STANDARD

The block diagram of the JPEG2000 encoder is illustrated in Fig. 3(a). The discrete transform is first applied on the source image data. The transform coefficients are then quantized and entropy coded, before forming the output code stream (bit stream). The decoder is the reverse of the encoder (Fig.4.1b). The code stream is first entropy decoded, de-quantized and inverse discrete transformed, thus resulting in the reconstructed image data.

Before proceeding with the details of each block of encoder in Fig. 1, it should be mentioned that the standard works on image tiles. The term 'tiling' refers to the partition of the original (source) image into rectangular non-overlapping blocks (tiles), which are compressed independently, as though they were entirely distinct images. Prior to computation of the forward discrete wavelet transform (DWT) on each image tile, all samples of the image tile component are DC level shifted by subtracting the same quantity (i.e. the component depth). DC level shifting is performed on samples of components that are unsigned only. If colour transformation is used, it is performed prior to computation of the forward component transform. Otherwise it is performed prior to the wavelet transform.

At the decoder side, inverse DC level shifting is performed on reconstructed samples of components that are unsigned only. If used, it is performed after the computation of the inverse component transform. Arithmetic coding is used in the last part of the encoding process. The MQ coder is adopted in JPEG2000. This coder is basically similar to the QM- coder adopted in the original JPEG standard [1]. The MQ-coder is also used in the JBIG-2 standard [7]. To recapitulate, the encoding procedure is as follows [8, 9]:
The source image is decomposed into components.

- The image and its components are decomposed into rectangular tiles. The tile-component is the basic unit of the original or reconstructed image.
- The wavelet transform is applied on each tile. The tile is decomposed in different resolution levels.
- These decomposition levels are made up of sub bands of coefficients that describe the frequency characteristics of local areas (rather than across the entire tile-component) of the tile component.
- The sub bands of coefficients are quantized and collected into rectangular arrays of "code-blocks".
- The bit-planes of the coefficients in a "code-block" are entropy coded.
- The encoding can be done in such a way, so that certain ROI's can be coded in a higher quality than the background.
- Markers are added in the bit stream to allow error resilience.
- The code stream has a main header at the beginning that describes the original image and the various decomposition and coding styles that are used to locate, extract, decode and reconstruct the image with the desired resolution, fidelity, region of interest and other characteristics.
- The optional file format describes the meaning of the image and its components in the context of the application. It should be noted here that the basic encoding engine of JPEG2000 is based on EBCOT (Embedded Block Coding with Optimized Truncation of the embedded bit streams) algorithm, which is described in details in [20, 21].

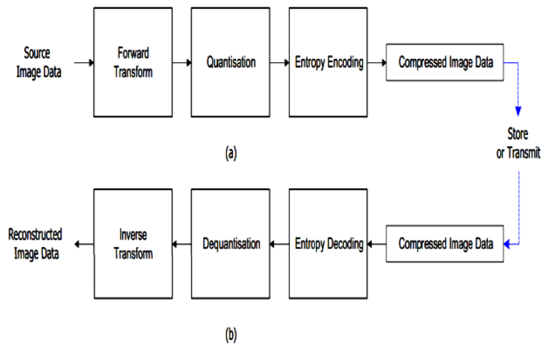

Fig.3. Block diagrams of the JPEG2000 (a) encoder and (b) decoder.

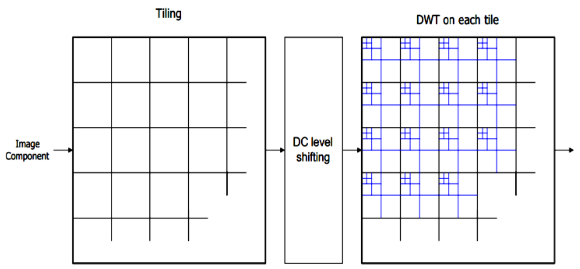

Fig.4. Tiling, DC level shifting and DWT of each image tile component.

III. PROPOSED METHODOLOGY

The methodology of this paper proposes a serious modification of the available JPEG 2000 for achieving higher compression as compared to the available JPEG 2000 standard. Hence first part of this paper is to modify JPEG 2000 termed as modified JPEG 2000. The basic idea of JPEG 2000 is discussed in figure (3), the main modification is the preprocess the image with a transfer function given by equation (1), which makes the image more suitable for JPEG 2000 technique and hence able to provide higher compression with less error. The modified JPEG 2000 proposed is shown in figure (5).

$$N_{mn} = T(X_{mn}) = \left[1 + \frac{X_{max} - X_{mn}}{F_d}\right]^{-F_e} \qquad (1)$$

Where F_e, F_d are constants, and
X_{max} = Maximum gray value of input image.
X_{mid} = Mid gray value of input image.

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$$F_d = \frac{X_{max} - X_{mid}}{0.5^{\frac{-1}{F_e}} - 1}$$

And N is the new transformed image, which is suitable for JPEG compression.

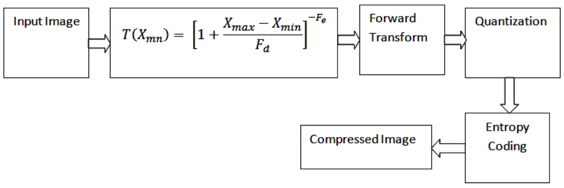

Figure (5) Proposed Modified JPEG2000-DWT (i.e. Modified JPEG2000)

IV. RESULTS AND DISCUSSIONS

The algorithm has been successfully developed and implemented in MATLB 7.10 to develop an efficient gray image compression. The following section deals with the description and discussion about various results obtained from the developed algorithm and normal JPEG 2000. Since it is not possible to estimate the performance of any algorithm on the basis of single image, hence for the performance evaluation of the developed algorithm three different gray images has been used. These images are shown in figure (6), figure (7) and figure (8). To compare the results obtained from the developed algorithm and normal JPEG 2000 two most important image compression parameters are used.

1. Compression Ratio (CR).
2. Root Mean Square Error (RMSE).

To show the compression and decompression process by using developed algorithm on first input image i.e. autumn.tif. Whose size is 206X345 and memory requirement to store is 71070 bytes shown in figure (6). For the performance assessment of developed algorithm on compression and decompression processes, the value of parameter level of decomposition is fixed to 5. The results obtained after the compression and decompression process using normal JPEG 2000 (NJPEG2000) and Modified JPEG 2000 (MJPEG2000) are shown from figure (6.1), figure (6.2) and figure (6.3).

Figure (6.1) input image.

Figure (6.2) Output image using (NJPEG2000)

Figure (6.3) Output image using (MJPEG2000)

The compression parameters obtained after first input image compression and decompression process using NDWT and FDWT are as follows.

S. No.	Parameters	Results for NJPEG2000	Results for MJPEG2000
1	Bi (size of first input image in bytes)	71070 bytes.	71070 bytes.
2	Bc (size of first compressed	66256 bytes.	2884 bytes.
3	Bo (size of first decompressed	71070 bytes.	71070 bytes.
4	Cr1	22.9703	197.1429
5	R.M.S.E1	10.9844	35.1643

Similarly the results obtained for second input image ie. (lena.jpeg), who's Size, is 415X445 and memory requirement to store is 180525 bytes are shown from figure (7.1) to figure (7.3). The compression parameters obtained after Second input image compression and decompression process using normal JPEG 2000 (NJPEG2000) and Modified JPEG 200 (MJPEG2000) are as follows.

Figure (7.1) input image.

Figure (7.2) Output image using (NJPEG2000)

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Figure (7.3) Output image using (MJPEG2000)

S. No.	Parameters	Results for NJPEG 2000	Results for MJPEG2000
1	Bi (size of first input image in bytes)	180525 bytes.	180525 bytes.
2	Bc (size of first compressed	121096 bytes.	7334 bytes.
3	Bo (size of first decompressed image in	180525 bytes.	180525 bytes.
4	Cr2	30.6807	196.9185
5	R.M.S.E2	8.1344	34.2543

Again the results obtained for Third input image i.e. (football.jpeg) Size 256X320 and memory requirement to store is 81920 bytes are shown from figure (8.1) to figure (8.3). The compression parameters obtained after third input image compression and decompression process using normal JPEG 2000 (NJPEG2000) and Modified JPEG 2000 (MJPEG2000) are as follows.

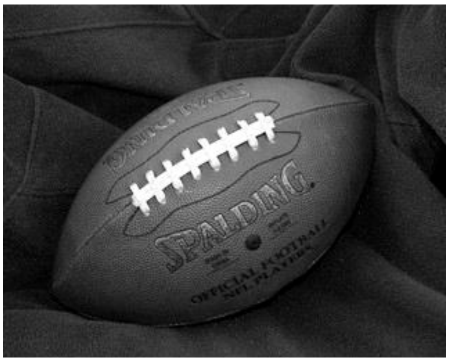

Figure (8.1) input image.

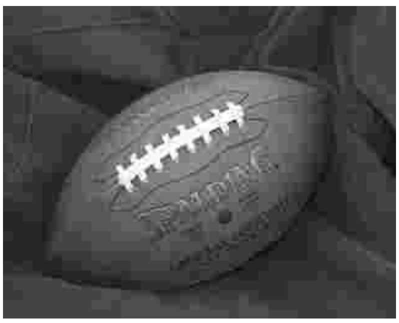

Figure (8.2) Output image using (NJPEG2000)

Figure (8.3) Output image using (MJPEG2000)

S. No.	Parameters	Results for NJPEG 2000	Results for MJPE G2000
1	Bi (size of first input image in bytes)	81920 bytes.	81920 bytes.
2	Bc (size of first compressed	42336 bytes.	1878 bytes.
3	Bo (size of first decompressed	81920 bytes.	81920 bytes.
4	Cr3	39.1587	348.9670
5	R.M.S.E3	9.5739	44.9676

V. CONCLUSIONS

In this Modern era image Transmission and processing plays a major role, and during the transmission and reception the image storage plays very important and crucial role. In the present scenario the technology development wants fast and efficient result production capability. This paper has brought forward some serious modifications on available JPEG 2000 image compression method. After the successful implementation of the proposed modification it has been found the modification proposed in conventional JPEG 2000 leads to the efficient solution to provide higher compression as compare to available JPEG 2000.

In addition to this in the result section it is found that though the proposed modification generates very high compression ratio but simultaneously increases the compression error. The key concept behind the acceptance of this increment in the compression error is that the change in error percentage is very small as compare to change in compression ratio. Hence the proposed modified JPEG 2000 provides efficient compression for gray scale images.

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BIOGRAPHIES

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