Use of Wavelet Transform Extension for Graphics Image Compression using JPEG2000 Standard

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ABSTRACT

The new image compression standard JPEG2000, provides high compression rates for the same visual quality for gray and color images than JPEG. JPEG2000 is being adopted for image compression and transmission in mobile phones, PDA and computers. An image may contain the formatted text and graphics data. The compression performance of the JPEG2000 behaves poorly when compressing an image with low color depth such as graphics images. In this paper, we propose a technique to distinguish the true color images from graphics images and to compress graphics images using a wavelet transform extension under JPEG2000 standard that will improve the compression performance. This method can be easily adapted in image compression applications without changing the syntax of compressed stream of JPEG2000.

Keywords: JPEG2000, JPEG, Entropy, Discrete Wavelet Transform (DWT), Down-sampling Factor Style (DFS)

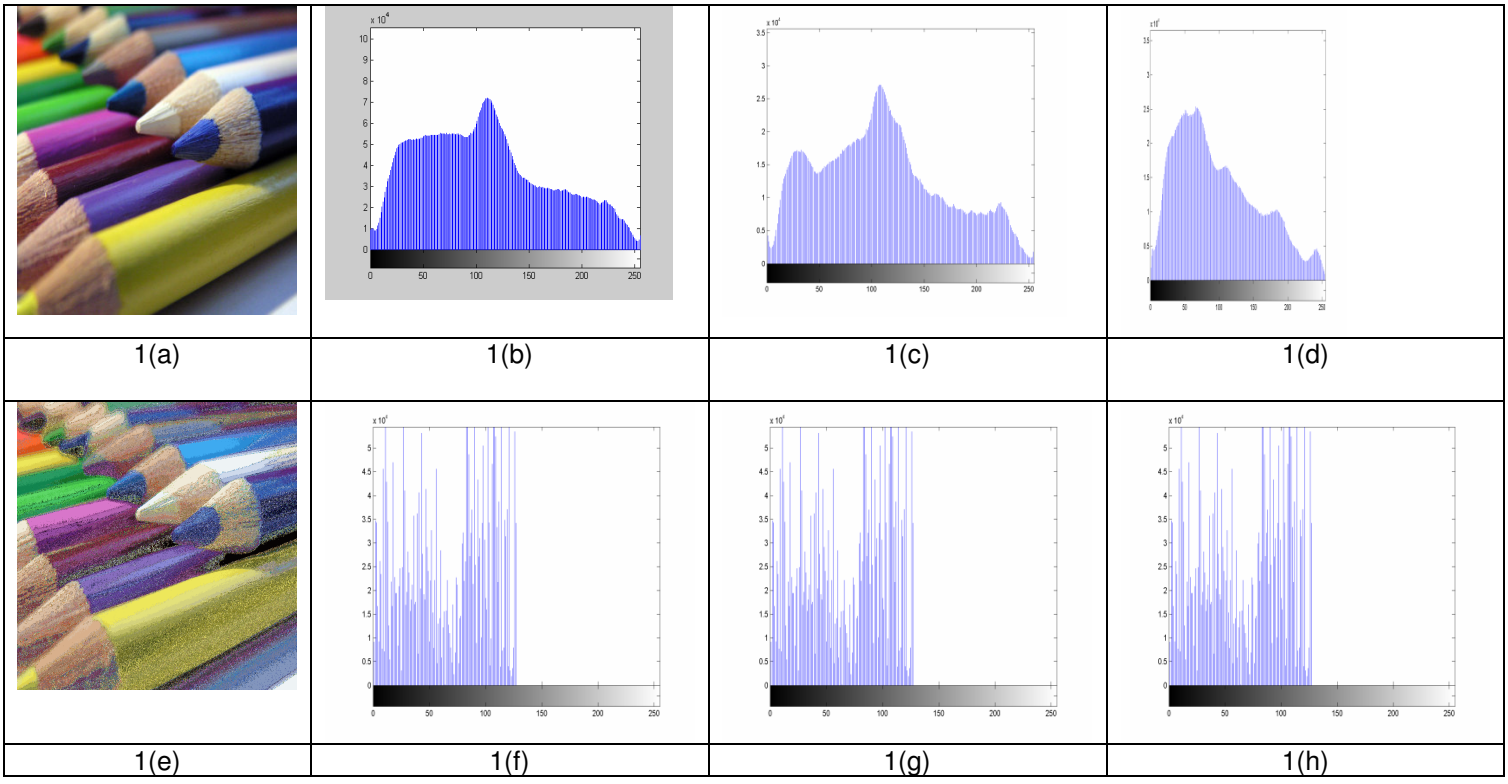
1. INTRODUCTION

JPEG2000 is state of the art image coding standard that resulted from the joint efforts of International standard Organization (ISO) and International Telecommunications Union (ITU). The Part 1 of the JPEG2000 standard describes core coding system [1]. But, when an image contains graphics type data, such as clips or logos, the performance of the JPEG2000 degrades due to the fact that these graphics images are either using color palette with low color depth or containing objects with solid areas and a limited number of colors. A general lossless image compression of JPEG2000 standard contains two steps. The first step, image de-correlation step is used to reduce the spatial redundancy of an image. This step provides the more compact representation of the image. The second step is the entropy encoding in which the de-correlated image is processed by an entropy encoder using some variable length coding techniques. But in case of graphics type images, the de-correlation step of JPEG2000 is actually degrading the image compression performance.

Some techniques have been proposed to compress the graphics images. Banerje *et. al.*[8] proposed a post processing technique to minimize the ringing distortions at low bit rates. Although post-processing technique gives better result but it adds to the complexity to the JPEG2000 codec. Tsai *et al.* [6] used the concept of entropy to distinguish the graphics images and true color images, and then compress the graphics images by bypassing the DWT step of the JPEG2000 codec.
In this paper, we proposed a simple method which still works under the framework of the JPEG2000 to improve the compression performance for the graphics type images. The idea is to use the different wavelet decomposition structure than the normal dyadic decomposition structure for the graphics images. The entropy is used to distinguish a graphics type images and true color images.
The rest of the paper is organized as follows. In Section 2, we present our key observation regarding the compression performance issue and review the concept of entropy of an image. The proposed method will be described in section 3. Simulation results of the proposed method are shown in section 4. Conclusion and future work will be discussed in section 5.

2. KEY OBSERVATIONS

Fig. 1(a) shows a true color image with 256 colors per channels. The histograms of Red, Green and Blue components are shown in Fig. 1(b) - (d). The image has very nice color distributions. In order to observe the behavior of a graphics image with low colors, we convert the pencil image into an image, as shown in Fig. 1(e), with 128 colors (as described in [5]). As shown in Fig. 1(f) – (h), the RGB histograms are very discrete. This observation inspired the idea of using the "entropy" to distinguish the true color image and graphics images and compress the graphics images using an wavelet transform extension method under JPEG2000 standard that will improve the compression performance. In the next sub-section, we will provide the quick overview for JPEG2000 standard.



1(a)	1(b)	1(c)	1(d)
1(e)	1(f)	1(g)	1(h)

FIGURE 1: (a) Original Pencil image with 256 colors (b)- (d) Histograms of (a)'s color channels; (e) image with reduced color depth (128 RGB colors). (f) – (h) Histograms of (e)'s color channels.

2.1 OVERVIEW OF JPEG2000 STANDARD

In this section, we present an overview of JPEG2000 with emphasis on concepts related to the ideas presented in this paper. In JPEG2000 [1-4], the first stage consists of (optionally) dividing the input image into non-overlapping rectangular tiles. For multi-component images, an optional component transform can be applied to decorrelate the components. These transformed components are known as tile components. An irreversible or reversible wavelet transform is then applied to each tile component to decorrelate the samples of the image, which is to be compressed. The irreversible transformation is used for lossy compression and reversible transformation for lossless compression. Each component of a tile is independently transformed by the DWT [11]. For lossy compression, 9/7 irreversible wavelet transformation is used and for lossless compression, 5/3 reversible wavelet transformation is used. The wavelet transform creates the decomposition levels. These decomposition levels are subbands of coefficients that characterize the local frequency of the tiles. For lossy compression, these subbands are then quantized. After quantization, each subband is divided into non overlapping rectangular blocks, called code blocks. Code blocks are the basic coding unit for entropy coding. Encoding of the blocks is done independently and the size of the block is typically 32 x 32 or 64 x 64. The entropy encoding in JPEG2000 consists of a fractional bit plane coding (BPC) and binary arithmetic coding (BAC). The combination of both coding is also known as Tier-1 coding in the standard. BPC has three passes in each bit plane: Significance Propagation Pass, Magnitude Refinement Pass, and Cleanup Pass. Each of the pass generates context models and the corresponding binary data. The output of the BPC and BAC produces the compressed bit stream. So an independent bit stream is generated for each code block. All these bit streams are combined into a single bit stream using Tier-2 coding, which is based on the output of the rate distortion optimization [4].

The structure of a simple JPEG2000 codestream contains the precincts and packets. A precinct is formed by grouping together the codeblocks that corresponding to a particular spatial location at a given resolution. Compressed data from each precinct are arranged to form a packet. Each packet contains a header and a body. The packet header contains information about the contribution of each codeblock in the precinct to the packet, while the body contains compressed coding passes from the codeblocks. Packets that belong to a particular tile are grouped together to form a tile stream, and tile streams are grouped together to form the JPEG2000 codestream. Similar to packets, tile streams are composed of a header and a body. The EOC marker indicates the end of the codestream.

2.2 ENTROPY OF AN IMAGE

In Information theory [5], entropy is the expected length of a binary code over all possible samples of a source. The entropy is defined as

$$E = -\sum_{i=0}^{N} p(a_i)\, log_2\, p(a_i)$$

Where N is the no of samples of the image and $p(a_i)$ is the probability of occurrence of samples a_i in the image.

The entropy provides a bound for compression that can be achieved. The entropy of an image will be a good indication for distinction of true color images or graphics images.

3. PROPOSED METHOD

JPEG2000 coding standard uses the DWT transform for the purpose of de-correlation of image pixels. We applied JPEG2000 part-2 downsampling factor styles (DFS) [2] features to implement the extension of wavelet decomposition structure. In our method, the first DWT transform level splits the image components only in vertical direction against the JPEG2000 decomposition in which the DWT transform decomposes the image in horizontal and vertical directions.

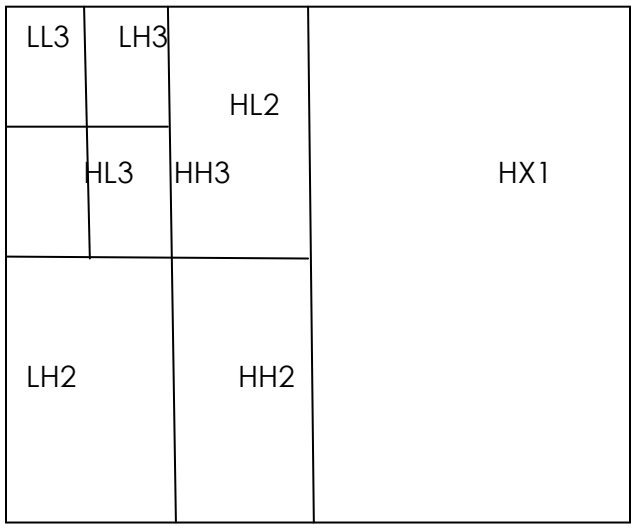


FIGURE 2: Non Dyadic wavelet decomposition

Subsequent DWT levels use full horizontal and vertical splitting for all image components, as shown in Figure 2. Here, the first level DWT transform is performed only on rows of the input image and it decomposes image into LX1 and HX1, where H stands for higher subimage , L stands for lower subimage and X denotes that no transform was performed on the columns. The second level decomposes LX1 into LL2, LH2, HL2 and HH2. No operation is carried on HX1. Then subsequent wavelet transformations split the LL portion into four subbands, as like a dyadic decomposition. The information of this non dyadic decomposition is stored into SIZ marker of the JPX files. In this method, there will be no extra overhead at the decoder side.

4. EXPERIMENTAL RESULTS

To observe the impact of different color depths, we gradually reduced the color depth from 256 colors to 4 colors per channel. We first applied the DWT decomposition method of JPEG2000 with five levels of using the kakadu [7] software. Then we applied the extension of DWT decomposition under the JPEG2000 standard. In both methods, the code blocks are 64x64 sizes. The proposed method outperforms the JPEG2000 standard, when the input image has less no. of colors.

Table1: Compression size comparisons and entropy values

Image	No of Colors		256 colors	128 colors	64 colors	32 colors	16 colors	8 colors	4 colors
Pencils.tif (3.12 MB) [9]	Entropy		7.82	6.66	5.78	3.80	3.83	2.87	1.96
	Compressed Size	JPEG2000	2189	1532	1054	689	455	249	142

	(Kilo Bytes)	Proposed Method	2250	1382	953	627	416	230	140
Icon.tif (509 KB) [10]	Entropy		4.92	4.05	3.53	2.89	2.70	2.22	1.68
	Compressed Size(Kilo Bytes)	JPEG2000	120	61	49	36	24	16	16
		Proposed Method	124	59	46	33	21	14	14

It is clear that for the images having very limited number of colors, the proposed method performs better than the JPEG2000 standard.

5. CONCLUSION & FUTURE WORK

Based on the simulation results, it is clear that the performance of JPEG2000 degrades when it compresses the images having low color depth such as graphics images. The performance of JPEG2000 improves significantly using JPEG2000 Part-2 downsampling factor styles. We used the entropy to distinguish the true color image or graphics images. The proposed method can be easily adapted in compression applications for graphics or drawing type images without changing the syntax of compressed bit stream of JPEG2000. This method can be extended to compress the video sequences under the JPEG2000 standard.

6. REFERENCES

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