A DETAIL PRESERVED COMPRESSION BASED ON CONTOURLET TRANSFORM[1]

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ABSTRACT:

It is well known that the commonly used separable extensions of one-dimensional transforms, such as the wavelet transform, have limitations in capturing the geometry of image edges. But natural scene images always have geographic lines, such as textures, edges which can not be well reconstructed when compressed by using one-dimensional transform. So in lossy compression of images, it is important to find a method which can best preserve the image by using a small description. To solve this problem, in this paper, we present a new compression method which can preserve one of the most important cues of image: the directional details. In order to show the ability of detail preserving lossy coder we present tests using typical images with much directional information, and a comparison between wavelets and the new wavelet based contourlet transform(WBCT) is made. Finally, we present the results obtained by using image quality assessment method. Our experiments demonstrate that the decompressed images based on WBCT can preserve more directional information than wavelet transform, which can be used efficiently in future image processing such as classification, edge detecting and so on.

1. INTRODUCTION

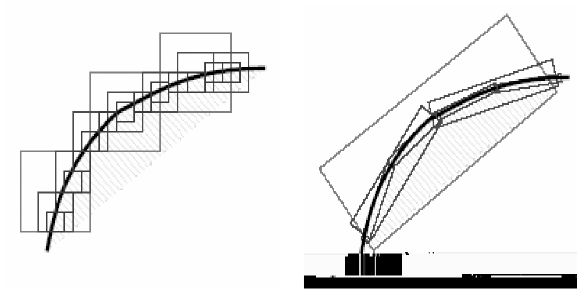
In recent years, a considerable effort have been made to design image compression method in which the main goal is to obtain good quality of decompressed images even at very low bit rates(O. O. Vergara Villegas, 2006; K. R. Namuduri and V. N. Ramaswamy, 2003). Due to the great use of digital information, image compression becomes imperative in different areas such as image storage, transmission and processing. At these areas the representation of the information needs to be efficient. The goal of image coding is to reduce the bit rate for signal transmission or storage while maintaining an acceptable image quality for different purposes (D. Schilling and P. C. Cosman, 2003).

Research of biologists on human vision system and natural scene images static model shows that: the best image representation should have characters below (Minh N.Do, and Martin Vetterli, 2005):

1) **Multiresolution**. The representation should allow images to be successively approximated, from coarse to fine resolutions.
2) **Localization**. The basis elements in the representation should be localized in both the spatial and the frequency domains.
3)**Directionality**. The representation should contain basis elements oriented at a variety of directions, much more than the few directions that are offered by separable wavelets.

A digital image is mainly composed by: edges, edge associated details and textures, and this three parts are very important in reconstructing an image. So in image compression, it is very necessary to preserve this information to get a good quality of reconstructed image. How to save these parts of an natural scene image by using a small description is a question that considered by many researchers.

Imagine that there are two painters, one with a "wavelet"-style and the other with a new style, both wishing to paint a natural scene. Both painters apply a refinement technique to increase resolution from coarse to fine. Here, efficiency is measured by how quickly, that is with how few brush strokes, and one can faithfully reproduce the scene, which is shown below in Figure 1 (Minh N.Do, and Martin Vetterli, 2005).



(a) Wavelet (b) New scheme

Figure 1. Wavelet versus new scheme: illustrating the successive refinement by the two systems near a smooth contour, which is shown as a thick curve separating two smooth regions?

When a smooth contour is being painted, as shown in Figure 1, we can clearly see the limitation of the wavelet-style painter who needs many fine dots to capture the contour, while the new scheme can make different elongated shapes and in a variety of directions following the smoothness of the contour. This decide that wavelet transform can not take advantage of the geographic character of natural images, and it is not the best and the most sparse representation method of data. So a new function

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representation method is developed recently, that is Multiscale Geometric Analysis (MGA).

2. DIRECTIONAL DETAIL PRESERVING IMAGE CODING SYSTEM

An image contains several features that exhibit the ability through which the image can offer information to people about the objects presented in the image.

In order to design a feature preserving lossy image coder it is important first, identify the features of the image to preserve and second, spend more bits to represent the important information and sacrifice fidelity or quality in other image regions (D. Schilling and P. C. Cosman, 2001).

2.1 Compression scheme

The structure of our compression system is shown below in Figure 2. We applied typical hierarchical dyadic decomposition scheme with filter banks: 5/3 biorthogonal. Coding algorithm is based on bitplane coding method. For wavelet transform, 5-level (for 512*512 image) decomposition was done. As directional decomposition is not suit to low-frequency subbands, only the two high-frequency levels were decomposed by directional filters, for each subband, 8 directions were made. After decompression, the images are evaluated by structure similarity method which is more appropriated here than the PSNR method.

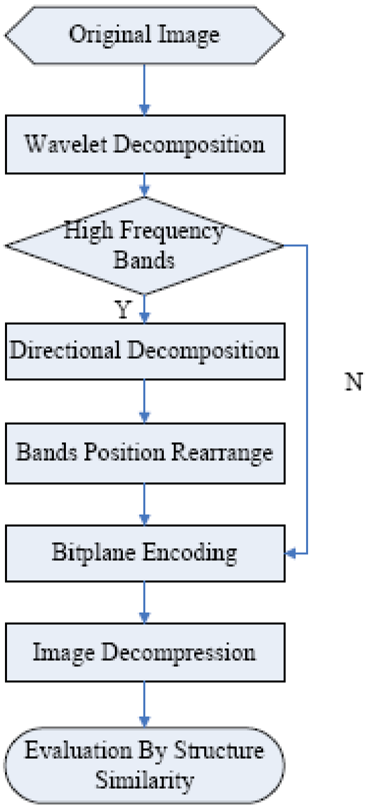
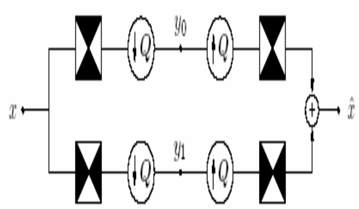


Figure 2. The structure of our compression system

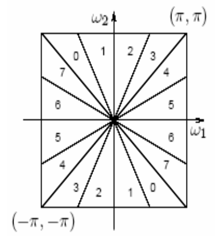
2.2 The directional filter banks

Directional Filter Bank (DFB) was designed to capture the high frequency (representing directionality) of the processing image. Bamberger and Smith constructed a 2-D directional filter bank (DFB) that can be maximally decimated while achieving perfect reconstruction. As shown in Figure 2(a)(LiYu, Lin, 2007).

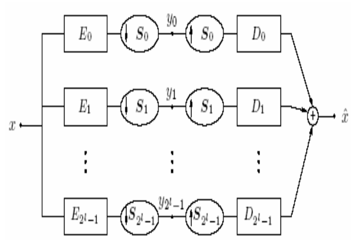
Do and Vetterli proposed a new construction for the DFB to avoid modulating input image, which we can obtain the desired 2-D spectrum division as shown in Figure 3(a). The simplified DFB is intuitively constructed from two building blocks. The first is a two-D spectrum into two directions: horizontal and vertical. As shown in Figure 3(b). The second is a shearing operator, which used to reordering the image samples. By appropriate combination of shearing operators together with two-direction partition of quincunx filter banks at each node in a binary tree-structured filter bank, shown in Figure 3(c).



(b) two-dimensional spectrum partition using quincunx filter banks with fan filters



(a) frequency partitioning



(c) the multichannel view of an l-level tree-structured DFB

Figure 3. The directional filter bank

2.3 The Wavelet Based Contourlet Transform (WBCT)

The Contourlet Transform (CT) redundancy occurs at the Laplacian pyramid decomposition stage. As a result we obtain two images, the first one resulting from low pass approximation, and the second one obtained from the high pass approximation. The image of details obtained (resulting from high pass) has always the same size of the immediately anterior, because we do not have resolution reduction. The directional decomposition is computed with the detailed image, by that, if we made more pyramidal decompositions we generate at least a half more information of the above level as redundancies. In order to take advantage of the directionality offered by CT and to avoid the redundancy, we can change the Laplacian pyramid decomposition with Mallat decomposition. As DFB is not suitable to handle the low frequency content (Minh N.Do, and Martin Vetterli, 2005), it is important to combine the DFB with a multiscale decomposition, where the low frequencies of the image are removed before applying the DFB. This is the main idea behind a new transform called Wavelet Based Contourlet Transform (WBCT) which is a non-redundant transform. For the WBCT it is important to ensure that we can obtain the perfect reconstruction of an image for the best case. The process to compute the WBCT is as follows (Vivien Chappelier, 2004):

1. Compute the DWT of an image, and in this paper we compute only log2 (image size) -5 levels.

2. Design the directional filters, for this paper we select the directional db5/3 filters.
3. Performs the directional decomposition using the images: LH, HL and HH. The process is made using the usual 5/3 tap filter that decomposes an image with a maximum of 3 directions or 8 subbands at the finer wavelet subbands.
4. Repeat the step three with the next wavelet level of LH, HL and HH images, in this paper, we only do the directional decomposition to the two high-frequency levels.

In Figure 4. We show the process to compute the WBCT (LiYu, Lin, 2007)..

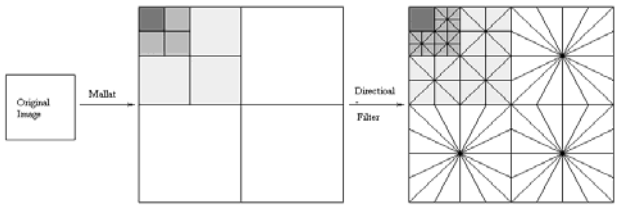


Figure 4. The process of WBCT

2.4 The Bitplane Coding Based On Significant Bits

Choose an adaptive encode method is very important for image compression, in this paper, we use the bitplane coding based on significant bits. For this method is very simple compared with SPIHT or EZW and time-saving. The matter is how to encode the bits so we can get a higher compression rate.

Before coding, two conceptions should be referred to (FeiPeng Li, 2003): the significant bit and the refinement bit. The significant bit is the first non-zero bit of a coefficient; the bits after the significant bit are called refinement bits. And the bits before the significant bit are called zero bits. For zero bits and significant bits, we encode them with a Multiple Quantization (MQ) coder, the sign bits are encoded by another MQ coder, but for refinement bits, we don't encode them but preserve directly for each one's probability of 0 or 1 is equal. The definition of the three kinds of bits and their encode method are shown in Figure 5.

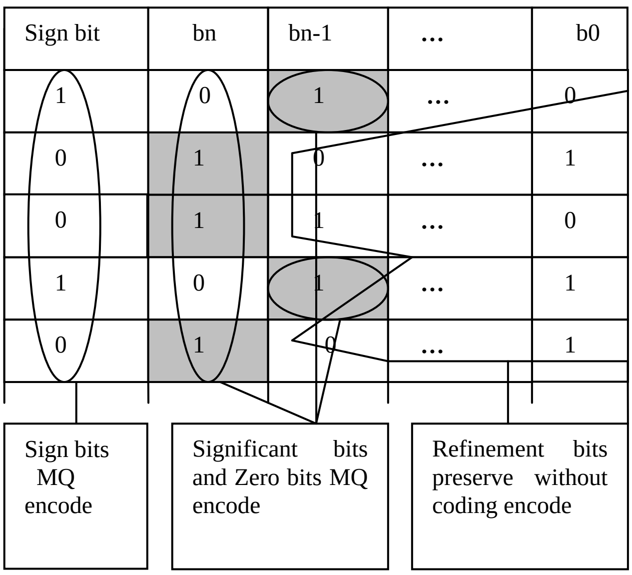


Figure 5. Coefficient bits encoding method (shadows are the significant bits)

2.5 Structure Similarity

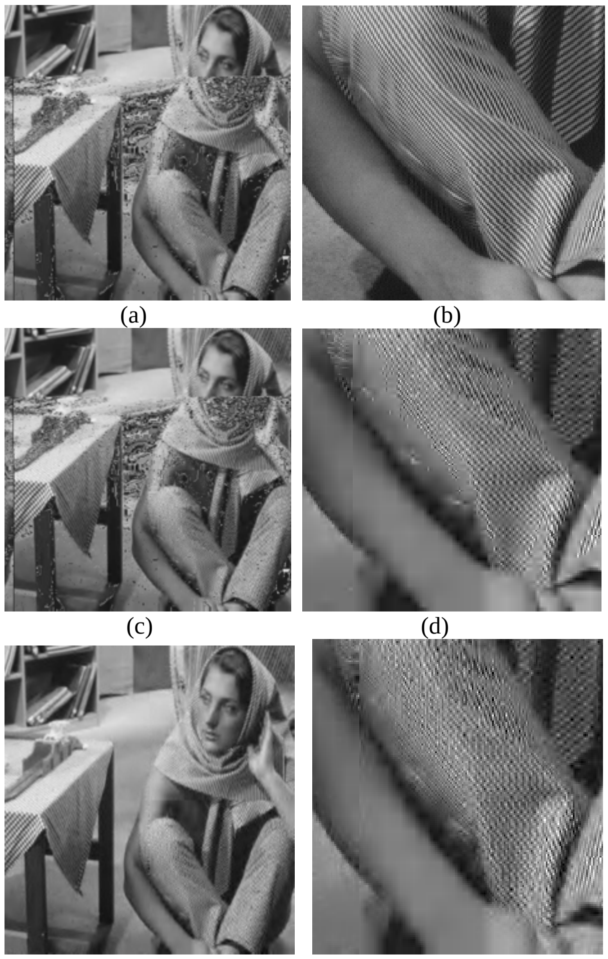
As we all know, the classical objective measure PSNR is not the only evaluation method of image quality, and it is not appropriated to measure the goodness of our coder. In this paper, we try to use a structure concerned method to evaluate the reconstructed images: the Structure SIMilarity (SSIM), represented by Zhou Wang (Zhou Wang et al. 2005). This method considered not just the error of each pixel between two images, but three different factors that decide the image quality: luminance, contrast and structure. So we choose SSIM as the image quality assessment method in this paper. The SSIM value has a constraint from 0 to 1, where high quality image has a larger SSIM value than a lower quality image.

3. TESTS, RESULTS AND DISCUSSION

In this paper, the experiments are based on the ImagZip2.0 system constructed by doctor Li FeiPeng et al. 2001. In order to best illustrate the detail preserving effect of our method, we choose the 512*512 size image"Barbara" which is abundant in directional details. We use this image to perform two different tests, the first one with a bit rate of 0.5 in order to obtain a compression factor of 16, and the second one with a bit rate of 0.2 in order to obtain a compression factor of 40.

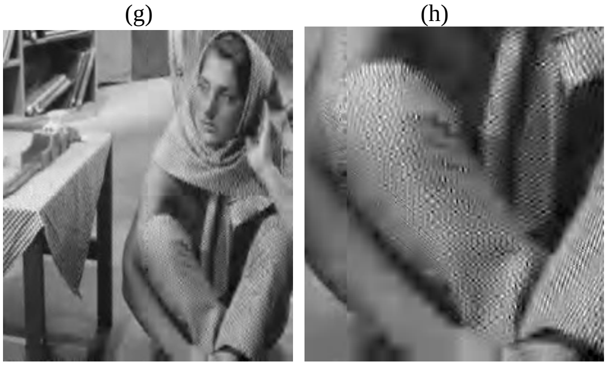
3.1 The comparing of the reconstructed images

The decompressed images obtained for test (bit rate of 0.5 and 0.2) using the DWT and the WBCT are shown in Figure 6.



(a) (b) (c) (d) (e) (f)

(g) (h)



(i) (j)

Figure 6. Decompressed images with bit rates at 0.5 and 0.2. (a)is the original image, (b) is the local-enlarged image of (a), (c) is the wavelet deconstructed image at the bit rate 0.5, (d) is local-enlarged image of (c), (e)is the WBCT deconstructed image at the bit rate 0.5, (f) is the local-enlarged image of (e), (g) is the wavelet deconstructed image at the bit rate 0.2, (h) is the local-enlarged image of (g), (i) is the WBCT deconstructed image at the bit rate 0.2, (j) is the local-enlarged image of (i).

From the images above, we can get to the conclusion that the image compressed by WBCT preserves more details than the wavelet method.

3.2 The image quality assessment by SSIM

After image decompression, we use the SSIM method to evaluate the quality of the reconstructed images. And the result comparing is shown in Table.1.

Compression Rate	SSIM	
	wavelet	WBCT
16	0.8445	0.8757
40	0.7405	0.7552

Table.1 The SSIM value of the reconstructed images (the original image without compression has an SSIM 1).

4. CONCLUSIONS AND FURTHER WORKS

In this paper we show the design and the implementation of a novel directional detail preserving image coder. The stages of the coder are: discrete wavelet transformation, directional filter deconstruction, bitplane coding, image compression and decompression. The possibility of coding images with directional detail preserving offers a wide range of applications in several industries in which this process is imperative such as medicine, mobile devices and face recognition. The classical objective measures such as PSNR are not appropriated to measure the goodness of this coder, this is due to the goal of the coder is not to improve the measures but preserve directional features.

There's still other work needs to be done. For example, the choosing of the wavelet base and the directional filter that can best dig out the advantage of WBCT (KE Li and HUANG Lian-qing, 2005). And the ImageZip2.0 compression system uses integer wavelet coding method which is disadvantage to our method because the WBCT coefficients are double float type. The loss of data precision makes the PSNR lower than the wavelet transformation. So it is necessary to find a suitable float encode method to improve our WBCT compression system.

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