An Efficient Image Compression By Overlapped Discrete Cosine Transform With Adaptive Thinning

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ABSTRACT

With the development of network and multimedia technology, real time image acquisition and processing is becoming a challenging task because of higher resolution, which imposes very high bandwidth requirement. Image compression is the only way to meet this requirement. The objective of image compression is to reduce redundancy of the image data in order to able to store or transmit data in an efficient form. This paper proposes a concept for digital image compression. The resulting compression scheme relies on overlapped (modified) discrete cosine transform which is based on the type IV Discrete cosine transform(DCT-IV) with the additional property of being lapped is proposed enabling a robust and compact image compression and adaptive thinning algorithms are recursive point removal schemes, which are combined with piecewise linear interpolation over detrimental Delaunay triangulations. Simulation result shows that compression of image done in this way enables more than 80% pixel level memory reduction at a peak signal-to-noise ratio level around 30 dB and less recursive points to produce a compressed image

Keywords— **Image compression, modified discrete cosine transform (MDCT), Thinning, Delaunay triangulation**

I. INTRODUCTION

Image compression is a vital area which addresses the problem of reducing the amount of data required to represent a digital image. It is a process intended to yield a compact representation of an image, thereby reducing the image storage and transmission requirements. Various image compression methods were proposed and developed as standards such as the joint photographic experts group (JPEG) standards [1] &[2], the discrete cosine transform (DCT)-based coding [3],[4]&[5], the wavelet-based coding [6]&[7] because of extensive research carried out in the field of image compression.

Image compression is minimizing the size in bytes of a graphics file without degrading the quality of the image to an unacceptable level. The reduction in file size allows more images to be stored in a given amount of disk or memory space. It also reduces the time required for images to be sent over the internet or downloaded from Web pages. There are so many different ways available to compress the image files. For the usage of internet, the two most common compressed graphic image formats are the GIF format and the JPEG format. The GIF method is commonly used for line art and other images in which geometric shapes are relatively simple whereas the JPEG method is more often used for photographs. Other two techniques of image compression are the use of fractals and wavelets. These methods have not gained widespread acceptance for use on the internet. However, both methods promise that they offer higher compression ratios than the JPEG or GIF methods for some types of images.

Image-compression algorithms are broadly classified into two categories depending whether or not an exact replica of the original image could be reconstructed using the compressed image. They are lossy and lossless. In lossy image-compression, there is a trade off between the compression ratio and the reconstructed image quality. If the distortion due to compression is tolerable, the increase in compression ratio becomes very significant. Lossy image-compression algorithms can be performed in either spatial domain or transform domains (frequency domain). Here limited bits are used to quantise the predictive value. There are different effective predictors, such as the gradient-adjusted predictor (GAP) [8] and the median adaptive predictor (MAP) [9]. Another way to compress the image is to firstly map the image into a set of transform coefficients using a linear, reversible transform, such as Fourier transform, discrete cosine transform or wavelet transform. The newly obtained set of transform coefficients are then quantized and encoded.

In transform coding scheme, transforms such as DFT (Discrete Fourier Transform) and DCT (Discrete Cosine Transform) are used to change the pixels in the original image into frequency domain coefficients (called transform coefficients). These coefficients have several desirable properties. One is the energy compaction property that results in most of the energy of the original data being concentrated in only a few of the significant transform coefficients. This is the basis of achieving the compression. Only those few significant coefficients are selected and the remaining is discarded. The selected coefficients are considered for further quantization and entropy encoding. DCT coding has been the most common approach in transform coding. It is also adopted in the JPEG image compression standard.

Lossless image-compression algorithms are error-free compression, which are widely used in medical applications, satellite imagery, business documentation, and radiography area because any information loss is undesirable or prohibited.
The performance of any image compression scheme depends on its ability to capture characteristic features of the image, such as sharp edges and fine textures, while reducing the number of parameters used for its modelling. The `compression standard JPEG2000 uses contextual encoding, which models the Markovian structures in the pyramidal wavelet decomposition of the image at very low bit rates, however, the oscillatory behaviour of wavelet bases typically leads to undesirable artefacts along sharp edges[10].

In many classical image compression methods, such as for the aforementioned DCT and DWT, the modelling is carried out by decomposing the image over a non-adaptive orthogonal basis of functions. The corresponding coefficients of the basis functions are then quantised, according to a specific quantisation step, which usually depends on a target compression rate. The performance of the resulting compression scheme depends on the approximation quality which results from the non-vanishing coefficients.

The proposed compression algorithm which combines MDCT[11] and adaptive thinning algorithms[12]. In first phase of encoding, the modified discrete cosine transform which is based on the type IV Discrete cosine transform(DCT-IV) with the additional property of being lapped is proposed enabling a robust and compact image compression .In second phase of encoding, compression scheme relies on adaptive thinning algorithms, which are used to remove the recursive points.

The rest of the paper is organised into 7 sections. Section II describes the related works. Section III presents the modified discrete cosine transform compression algorithm. Section IV explains the thinning methodology and associated compression algorithm. Section V gives the integration of MDCT and thinning. Section VI discusses the simulation results .Section VII concludes this paper.

II. RELATED WORK

Different compression schemes are proposed by different groups of researchers over modified discrete cosine transform based image compression and adaptive thinning. Both the compression techniques are used separately and lot of improvement are achieved by different researchers group in terms of low or no loss compression, speedy compression
Che-Hong Chen , IEEE et.al [11] have presented efficient recursive architectures for realizing the modified discrete cosine transform (MDCT) and the inverse MDCT (IMDCT) acquired in many audio coding systems

Rene' J. van der Vleuten, IEEE et.al [13] have developed a scalable image compression scheme with a good performance-complexity trade-off. Like JPEG, it is based on the 8 x 8 block discrete cosine transform (DCT), but it uses no additional quantization or entropy coding bit rate .
Ezhilarasi.P et.al IETE [12] have discussed about adaptive thinning algorithm which uses Delaunay triangulations method to remove the recursive point in the image.

Shizhong Liu, Student Member, IEEE et.al [14] have modelled blocking artifacts as 2-D step functions. In which a fast DCT-domain algorithm is proposed which extracts all parameters needed to detect the presence of, and estimate the amplitude of blocking artifacts, by exploiting several properties of the human vision system.

Jian Huang et.al [15] have proposed FPGA-based scalable architecture for DCT computation using dynamic partial reconfiguration. Which can perform DCT computations for eight different zones, i.e., from 1x1 DCT to 8x8 DCT

The proposed work involves the following steps:
1) The MDCT is two dimensional discrete cosine transform implementation which is based on the type IV Discrete cosine transform(DCT-IV) with the additional property of being lapped is proposed enabling a robust and compact image compression [11].
2) Adaptive thinning algorithm is employed which uses Delaunay triangulations method to remove the recursive point in the image and also to process the image further easily since the thinned image dealing only with edges[12].
3) Integration of all above methods is done to achieve less memory requirement, less recursive points, higher compression ratio and PSNR.

III.MDCT

Joint Photographic Experts Group (JPEG) is a commonly used standard technique of compression for photographic images which utilizes DCT. DCT separates images into parts of different frequencies (i.e. dc & ac components) where less important frequencies are discarded through quantisation and important frequencies are used to retrieve the image during decompression. Currently the standard Discrete Cosine Transformation (DCT) based algorithm of the JPEG is the most widely used and accepted for image compression. It has excellent compaction for highly correlated data. DCT separates images into parts of different frequencies where less important frequencies are discarded through quantisation and important frequencies are used to retrieve the image during decompression [16]. Compared to other input dependent transforms, DCT has many advantages: (1) It has been implemented in single integrated circuit, (2) It has the ability to pack most information in fewest coefficients But the disadvantage of DCT scheme is the “blocking artifacts” in reconstructed image at high compression ratio which degrades quality of reconstructed image. Also in DCT, edges of the reconstructed image are blurred but smooth. The above drawbacks are eliminated by MDCT which is based on a DCT of overlapping data.

The modified discrete cosine transform (MDCT) is a Fourier-related transform based on the type-IV discrete cosine transform (DCT-IV), with the additional property of being *lapped*: it is designed to be performed on consecutive blocks of a larger dataset , where subsequent blocks are overlapped so that the last half of one block coincides with the first half of the next block. This overlapping, in addition to the energy-compaction qualities of the DCT, makes the MDCT especially attractive for image compression applications, since it helps to avoid artifacts stemming from the block boundaries.

As a lapped transform, the MDCT is a bit unusual compared to other Fourier-related transforms in that it has half as many outputs as inputs (instead of the same number). In particular, it is a linear function F: $R^{2N} \rightarrow R^N$ (where **R** denotes the set of real numbers). The 2*N* real numbers $x_0, \ldots, x_{2N-1}$ are transformed into the *N* real numbers $X_0, \ldots, X_{N-1}$ according to the formula:

$$X_k = \sum_{n=0}^{2N-1} x_n \cos\left[\frac{\pi}{N}\left(n+\frac{1}{2}+\frac{N}{2}\right)\left(k+\frac{1}{2}\right)\right] \quad \text{--}\rightarrow (1)$$

The inverse MDCT is known as the **IMDCT.** The perfect invertibility is achieved by *adding* the overlapped IMDCTs of subsequent overlapping blocks, causing the errors to cancel and the original data to be retrieved.

The IMDCT transforms *N* real numbers $X_0, \ldots, X_{N-1}$ into 2*N* real numbers $y_0, \ldots, y_{2N-1}$ according to the formula:

$$y_n = \frac{1}{N}\sum_{k=0}^{N-1} X_k \cos\left[\frac{\pi}{N}\left(n+\frac{1}{2}+\frac{N}{2}\right)\left(k+\frac{1}{2}\right)\right] \quad \text{-}\rightarrow (2)$$

In the case of JPEG an 8 x 8 block of pixels is mapped to an 8 x 8 block of frequency components ,meaning that the amount of data to be entropy coded(output of DCT) is same as the original amount of data (input to the DCT). This desirable property is referred to as critical sampling. In the case of overlap-and- add (with 50% overlap), the transform block will have twice as many as blocks (of the same size) it has before or without overlapping. In this process the amount of data to be compressed has thus doubled, and critical sampling is lost. The modified discrete cosine transform(MDCT) overcomes this problem: whereas a standard DCT would map N samples of data to N new values, the MDCT maps an N-sample block, say x, to a block consisting of $\frac{N}{2}$ new values, say X, as illustrated in the below figure.

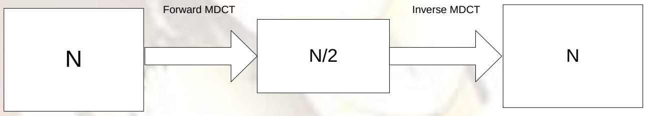

Figure.1. A block diagram description of the forward and inverse MDCT

The 8 x 8 blocks of frequency components are quantised by using the existing 1D case of 16-sample transform blocks illustrated with two dimensions to retain the JPEG’s existing well-defined structure. The 16 x 16 blocks of pixels will be applied first to its row, and then to the column of the resulting 16 x 16 matrix, there by implementing a 2D windowed MDCT. This transform therefore maps 16 x 16 transform blocks to 8 x 8 blocks of frequency components. Similarly using the 2D inverse transform it will be mapped back to 16 x 16 blocks. This concept is illustrated in the below block diagram.

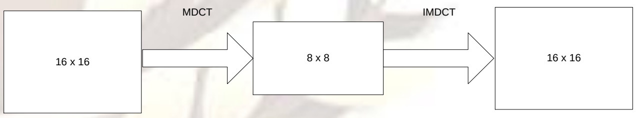

Figure2: Extending the IMDCT to two dimensions in order to obtain 8 x 8 transform blocks

By doing this, overlap adding is also extended to two dimensions. Each 2D transform block will have 8 neighbouring blocks to overlap with. Alternatively one could first apply to each row of an entire image; the same is then done to columns of the resulting output. In the end the same matrix say Y, consisting of 8 x 8 blocks of frequency components is obtained. To decode, the reverse process is applied, the first each column of Y is inversely transformed by overlapped and added then to the each row of the resulting output. By retaining 8 x 8 blocks of frequency components, the overall operation of DCT is retained by MDCT. The MDCT coefficients in an 8 x 8 block are roughly 4 times larger than DCT coefficients in an 8 x 8 blocks.

Algorithm

1: Original image is divided into blocks of 8 x 8.

2: Pixel values of a grey image ranges from 0-255 but MDCT is designed to work on pixel values ranging from -128 to 127. Therefore each block is modified to work in the range.

3: The transform blocks are formed using 50% overlap

4: Then normalized window function is applied to the blocks.

5: Time to frequency mapping is applied to these blocks, resulting in frequency components.

6: The frequency components are quantized & entropy encoded

7: The reverse process is done to obtain the decompressed image

IV.ADAPTIVE THINNING

Adaptive thinning constructs a hierarchy of sets of the most significant pixels, where for each set the image is approximated by the linear spline over the Delaunay triangulation of the pixels in the set.

Generic Formulation of Thinning:

Let $X = \{X_1,\ldots,X_N\} \subset R2$ denote a finite scattered point set in R^2, and let $f_X = (f(x_1), \ldots, f(x_N))^T \in R^N$ denote a corresponding data vector containing point samples taken from an unknown function $f : R^2 \rightarrow R$ at the points of X. Thinning is a recursive point removal scheme for bivariate scattered data, whose generic formulation is given by the following algorithm, where *n* is the number of removals[10].

Algorithm

(1) Let $X_N = X$

(2) FOR $k = 1, \ldots, n$

(3) Locate a removable point $x \in X_k$

(4) Let $X_{N-k} = X_{N-k+1} \setminus x$;

$X_{N-n} \subset \cdots \subset X_{N-1} \subset X_N = X$ ---(3)

Note that thinning constructs, for given data (X, f_x), a nested sequence of subsets of X, where the size $|X_k|$ of any subset X_k in (1) is k, $N-n \leq k \leq N$. Two consecutive subsets in equation (3) differ only by one point. In order to select a specific thinning strategy, it remains to give a definition for a removable point in step (3) above.

To remove the recursive points in the image we use the Delaunay triangulations method as shown in the figure below if we remove the vertex y from figure 3(a) the actual structure of the pentagon mentioned as before externally as shown in figure 3(b) and ensured that external points not removed from figure.

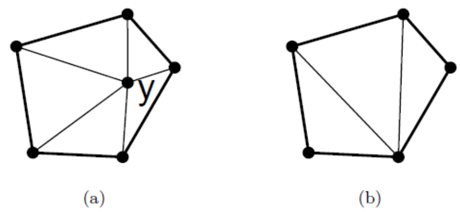

Figure 3: Removal of the vertex y, and retriangulation of its cell. The five triangles of the cell in (a) are replaced by the three triangles in (b).

A linear spline is a continuous function, which is piecewise linear over a partitioning of its domain $\Omega \in R^2$. Let the domain coincide with the convex hull [X] of the input point set X. If the convex hull [Y] of any subset $Y \subset X$, constructed by thinning, coincides with the convex hull of X and ensured that external points not removed from X. A convenient choice for the partitioning of Ω is the Delaunay triangulation D(Y) of Y .

Firstly, a Delaunay triangulation D(Y) of a finite planar point set Y is one, such that for any triangle in D(Y) its corresponding circumference does not contain any point from Y in its interior. This property is termed as the Delaunay property. Moreover, there is a unique triangulation of Y with the Delaunay property, provided that no four points in Y are co-circular. It is assumed that this condition on the given set X in order to avoid lengthy but immaterial discussions concerning the non-uniqueness of D(Y), for $Y \subset X$.

`Secondly, it is noted that the removal of one point y from Y requires an update of D(Y) in order to obtain the Delaunay triangulation $D(Y \setminus y)$. Due to the Delaunay property, this update of D(Y) is local. Indeed, the required retriangulation, incurred by the removal of the vertex y in D(Y), can be performed by the retriangulation of its cell C(y). It is recalled that the cell C(y) of y is the union of all triangles in D(Y) which contain y as a vertex. Figure 3(a) & 3(b) shows, for a vertex y in a Delaunay triangulation, the retriangulation of its cell C(y)

V.INTEGRATION OF MDCT & THINNING

Basic operation of the whole framework can be seen as the combined effect of MDCT and Adaptive Thinning methods. The functional block diagram is given in figure 4.

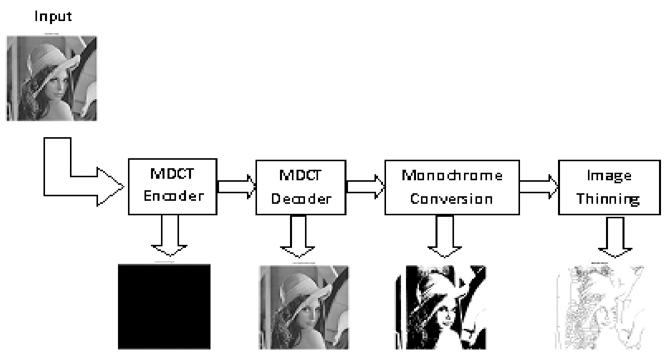

Figure 4: Functional block diagram

In the first phase of encoding, the modified discrete cosine transform which is based on the type IV Discrete cosine transform(DCT-IV) with the additional property of being lapped is proposed enabling a robust and compact image compression. Here the original lena image of 147 kB is compressed in to 7 kb image with compression ratio of 40 at PSNR around 30 dB.

In the second phase of encoding, compression scheme relies on adaptive thinning algorithms, which are recent multiresolution methods from scattered data approximation. Adaptive thinning algorithms are recursive point removal schemes, which are combined with piecewise linear interpolation over decremental Delaunay triangulations [9]. Here the compressed lena grey scale image is appeared as the thinned image of 57 kB which has less recursive points.

By combining the modified discrete cosine transform and thinning compression scheme, the memory size could be reduced which is taken care by the MDCT and the output of MDCT encoder image is again decoded back and this image is fed as input to thinning image model which further converters grey scale image into monochrome image that removes the recursive points from the encoded compressed image that makes regeneration of image by using minimal numbers of parameters of image during decoding . Here the output is monochrome image and it can be transmitted fast on network because here complexity is less as compared to other coding schemes. In is method we have two different output one is greyscale image format that from MDCT and another from Thinning module output that is monochrome but both images are in commercial standard JPEG2000 [10].

VI. SIMULATION RESULTS

As the original image shown in figure 5 is of 147KB is the CCD output which is in the PNG format and it is fed as the input to MDCT block encoder and its output is shown in figure 6 which is in the blocked format of homogenous type and having a limit of block size 8x8. Then it is fed into the MDCT decoder which generates the compressed image of size 7KB in JPEG format as shown in figure7. Since we use thinning operation, the grey scale image is required to be converted into monochrome image which is shown in figure 8 and then it is fed to Thinning block. Finally the thinned image output is given in figure 9 whose size is 57KB and it has less recursive points. By employing both the methods mentioned in this paper, both less memory space and less recursive points can be achieved.

Figure 5: Original lena image

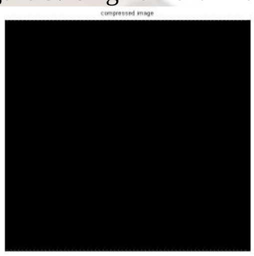

Figure 6: MDCT blocked image

Figure 7: Compressed lena image

Figure 8: Monochrome image of figure 7.

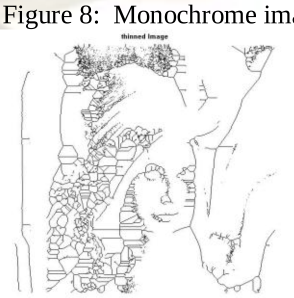

Figure 9: Thinned Image of the compressed image

Thus 147 KB original image is compressed to 7 KB at PSNR ratio around 30 dB in MDCT compression scheme
and 57 KB in Thinning method .The peak signal-to-noise ratio of cameraman image obtained for various compression methods are listed below in table1.

Method	PSNR
DCT	19.28
Wavelet	26.78
MDCT	29.1965

Table 1. Comparison of PSNR for various compression algorithm

The comparison of PSNR chart for various compression methods (DCT, DWT & MDCT) are shown in figure 10.

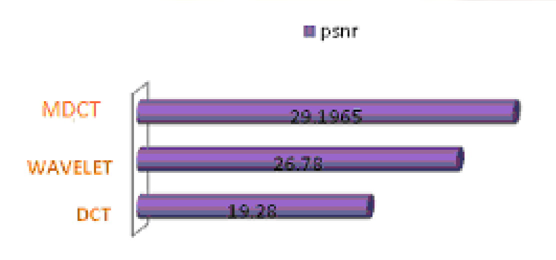

Figure 10: Comparison of PSNR for cameraman image.

The relationship between compression ratio and PSNR for lena image for proposed algorithm is plotted in figure 11.

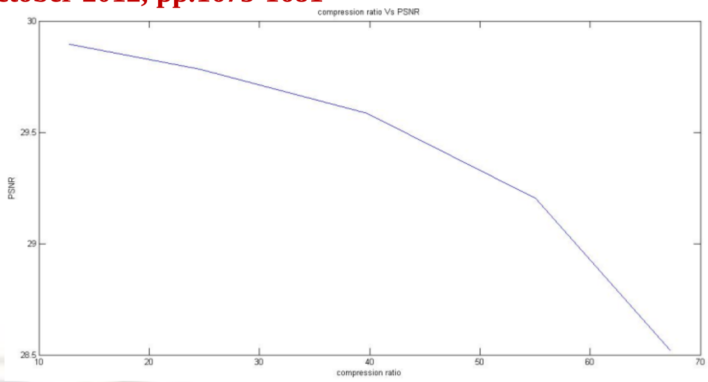

Figure 11: CR Vs PSNR for lena image

The comparison study of DCT,DWT & MDCT are depicted in figure 12 which shows better PSNR values for proposed method MDCT.

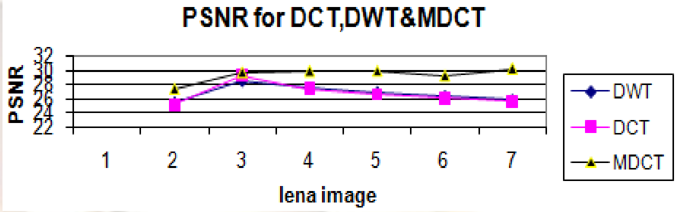

Figure 12: PSNR values for DCT,DWT&MDCT

The compression ratio and psnr values for three different images along compression size in MDCT and thinning algorithm is given in table 2.

S.No.	Original Image	Original Image Size	MDCT Size JPEG	Thinning Size JPEG	Compression ratio	PSNR In dB
1.	TIFF 	77 KB	3 KB	19 KB	24.5631	29.1965
2.	PNG 	147 KB	7 KB	57 KB	39.7489	29.5663
3.	GIF 	292 KB	7 KB	90 KB	39.7489	29.5635

Table 2. Image compression for different images

VII.CONCLUSIONS

This paper reports the integration of two compression schemes based on modified discrete cosine transform compression and adaptive thinning. This method generates three different images of a single raw image .They are: (1) Lena gray scale image in PNG format that is compressed by MDCT, (2) the image in the monochrome format, (3) thinned image. Since all the images are in JPEG2000 format and require very less memory as compared to other compression technology and also here it is proved that the high PSNR is obtained compared to DCT & DWT. The compression can be controlled by changing compression ratio in MDCT. Since thinned image is dealing with only edges of the objects in the image, further processing is very easy and fast because it contains minimum information about image and also it removes the recursive points. This new method is very useful for image or video based tracking and edge based tracking for the real time application where processor capabilities are limited and minimum. The simulation results illustrate that the proposed algorithm results in more than 80% pixel level memory reduction at a peak signal-to-noise ratio level around 30 dB and less recursive points to generate a compressed image.In future thinned image size is further reduced by using any of the morphological operations.

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