DCT/DPCM HYBRID CODING FOR INTERLACED IMAGE COMPRESSION

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ABSTRACT

By the nature of images, picture elements in local regions are highly correlated with one another. In such cases, image compression techniques are introduced to reduce the amount of data is needed to represent the same information, either exactly or approximately.

In this work DCT/DPCM hybrid approach have been designed and implemented for interlaced images. The image signal was first transformed row-wise using discrete cosine transform (DCT) and a differential pulse code modulation (DPCM) scheme then was used column-wise to get difference signal. For still images the same 3-bit quantizer was employed which makes quantization process easier. For interlaced images 3-bit quantizer was used for the odd field and 2-bit quantizer for even field, since the difference signal of the even field was very small.

A compression ratios of about 13:1 was obtained for interlaced image. Objective measurements showed a high peak to peak signal to noise ratio without noticeable impairment.

KEY WORDS: Interlaced, Hybrid image compression, DCT/DPCM, Discarding.

List of Abbreviations

Abbreviation	Meaning
1-D	One Dimensional
2-D	Two Dimensional
bpp	Bit per pixel

Abbreviation	Meaning
BR	Bit Rate
CR	Compression Ratio
DCT	Discrete Cosine Transform
DFT	Discrete Fourier Transform

Abbreviation	Meaning
DPCM	Differential Pulse Code Modulation
HVS	Human Visual System
IDCT	Inverse Discrete Cosine Transform
MSE	Mean Squared Error
PSNR	Peak to peak Signal to Noise Ratio
PCM	Pulse Code Modulation
RLC	Run Length Coding
SQ	Scalar Quantizer
SNR_{RMS}	The root-mean-square signal-to-noise ratio.
HVS	Human Visual System
IDCT 123	Inverse Discrete Cosine Transform
MSE	Mean Squared Error
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SQ	Scalar Quantizer
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List of symbols

Symbol	Description
d_q	Quantized difference
$I(r)$	The one dimensional function
$I(r,c)$	The two dimensional original image
$\dot{I}(r,c)$	The decompressed image.
L	Number of gray levels
r_i	Quantizer reconstruction levels.
S	Actual (present) sample value.

INTRODUCTION

Compression of digital images has been a topic of research for many years and a number of image compression standards have been created for different applications. A digital mage can be considered as two-dimensional array of samples I(r, c). [1, 2]

Due to the errors introduced by sampling and quantization of the actual scene, it is only an approximation of an actual scene could be obtained. Number of levels of intensity determines the Precision are expressed as the number of bits/sample. [3, 4]

It is well known that an analogue television picture is built up of lines. These pictures or frames are updated with a certain frequency (25 Hz or 30 Hz). At such a low frame rate the flicker in the TV picture is annoying. A way to solve this problem would be to increase the number of frames per second, to say 50 Hz; a method to increase the video update frequency and to lower the bandwidth usage is to use interlaced pictures. Interlacing doubles the frame update frequency, the odd and the even field of each frame is transmitted consecutively. Each field contains only half the information of a full frame. Interlacing works by scanning every odd line on the screen, followed by every even line in the second scan. [5, 6]

The image quality is measured either subjectively or objectively. The parameters that decide if a picture to be considered is of high quality will differ when either of them is used.

The subjective visual quality measurement plays an important role in visual communications. It is natural that human viewers should judge the visual quality of reconstructed images or video frames since they are the ultimate receivers of the data. [7]

Objective quality measurements are conducted by using electrical instrumentation. All types of objective video or image quality assessments are done by measuring the distortion as the difference (error) between the original and the reconstructed image by a predefined function.:

$$\text{error}(r,c) = \dot{I}(r,c) - I(r,c) \qquad (1)$$

Where: I(r, c) = the original image,

and $\dot{I}(r,c)$ = the decompressed image

The root-mean-square error is defined by square root of the error squared divided the total number of pixel in the image (N^2):

Another related metric, the Peak Signal-to-Noise Ratio (PSNR) metric, is defined as:

$$PSNR_{(dB)} = 10\log_{10} \frac{(L-1)^2}{\frac{1}{N^2}\sum_{r=0}^{N-1}\sum_{c=0}^{N-1}\left[\dot{I}(r,c) - I(r,c)\right]^2} \quad \ldots\ldots\ldots(2)$$

Where L = the number of gray levels (e.g., for 8 bit L = 256)

These objective measures are often used in research because they are easy to generate and seemingly unbiased. [8]

The most obvious measure of compression efficiency is the Compression Ratio (CR) metric which is often employed and is defined as:

$$CR = \frac{\text{original image}}{\text{compressed image}} \quad (3)$$

Sometimes compression is instead quantified by stating the *Bit Rate BR* achieved by compression in bpp (bits per pixel) and is defined by:

$$BR = \frac{\text{original image size in bit}}{\text{No of pixels of the image}} \quad (4)$$

The bit rate and compression ratio are simply related by: [9]

$$BR = (\text{BPP for origional image}) / CR \quad (5)$$

Compression algorithms can be divided into lossless and lossy algorithms depending on the type of coding used which will be determined by the particular needs of the user.

Lossless compression of images involves a completely reversible scheme by which the original data can be reconstructed exactly; it can achieve a compression ratio of up to 3:1. Run-Length coding and Huffman coding are some of the lossless compression methods used in image compression. [10]

In order to achieve high compression ratios with complex images, lossy compression methods are required. Lossy compression provides trade off between image quality and degree of compression.

In fact many lossy compression techniques are capable of compressing images with 10:1 to 20:1 and still retain high quality visual information.. The lossy methods include predictive coding, transform coding and the combination of both which is called hybrid coding. [11]

EXPERIMENTAL WORK

The hybrid system consists of five main stages, see Fig. (1), firstly the encoding process of the input still image into interlaced image by dividing the original image into two fields. Then each line in the field is divided into blocks of the same length. Each block is considered as a row vector, considering the odd field represented by every odd line in the image is the first field to be coded.

1D DCT is applied to transform each row vector in the odd field from spatial domain to frequency domain with the same dimension to be represented in a more compact form. The few low frequency coefficients represent the DCT packing of the image energy, where the high frequency coefficient can be discarded with little loss in energy; the discarded coefficients are replaced by zero coefficients. See Fig. (2).

As mentioned previously that DCT coefficients with the same horizontal frequency are highly correlated, a one dimensional first order DPCM is used for encoding the odd field. The predictor uses the vertical coefficient value for the prediction according to the equation (6).

But, for even field second order predictor is used because the current coefficient has two neighboring coefficients useful for prediction (previous and next vertical odd coefficients, see Fig. (2), the third order prediction is not possible.

The predicted value of T_4 is then given by:

$$\hat{T}_4 = a_7 \dot{T}_\circ + a_8 \dot{T}_2 \qquad (6)$$

Where: $\dot{T}_\circ$ and $\dot{T}_2$ is the reconstructed coefficient of $T_\circ$ and T_2 respectively. a_7 and a_8 are the prediction weighting coefficients for the even field. The prediction difference is then fed to the quantizer to obtain the quantized difference which adds to the predicted value to get the reconstructed coefficient. Each field quantized in different quantizer, (2bits) quantizer is used with the even field, while as for odd field (3bits) quantizer is used.

The same DPCM system is used to decode each field coefficients, and then the DPCM decoding coefficients is applied to 1D-IDCT to reconstruct the original interlaced image data. The hybrid system (DCT/DPCM) for the interlaced image is illustrated in the algorithm below.

Algorithm 1:

Input: The original interlaced image

Output: The Compressed interlaced image

Step 1: Selection of the original interlaced image.

Step 2: Divide each field of the interlaced image into row vectors.

Step 3: Apply One Dimension-Discrete Cosine Transform (*1D DCT)* to each field row wise considering odd field first**.**

Step 4: Discarding the *DCT* coefficients that represent high frequencies.

Step 5: Apply *DPCM* coding to *DCT* coefficients using first order prediction for odd field , Second order prediction for even field.

Step 6: *DPCM* reconstruction of the transformed coefficients.

Step 7: Inverse *DCT:* Apply the inverse *1D DCT* to the reconstructed coefficients obtained from step 6 to get the reconstructed image.

Step 8: End.

SIMULATION RESULTS

To evaluate the hybrid system performance with the applied *Saturn* image of size (256×256) with 256 gray levels. Two major measurements have been employed, namely the objective and subjective tests.

In this system each line is divided into blocks. Each block is considered as a row vector of 128 pixels. 1D DCT is applied to convert each vector of pixels into a vector of 128 transformed coefficients. 1D DCT packing the energy into few numbers of transformed coefficients associated with low frequencies, the high frequency coefficients are discarded and replaced by zero coefficients. The discarding process provides a tradeoff between CR and PSNR.

Fig.3 (b, c, d and e) show the *Saturn* reconstructed images using (64, 51, 39 and 32) low frequency coefficients respectively. They show a higher subjective quality. Comparing the reconstructed images with the original image, no noise in smooth

127 area and no edge degradation are evident.

(Table 1) list the objective test based on CR and PSNR. Generally when the bit rate decreases the PSNR will decreases and the quality will be corrupted by smearing in the edge

CONCLUSIONS

From the results obtained, one can conclude the following points:

1-The actual efficiency of the compression system depends to some extent on the original image quality.

2-The discarding process of high frequency DCT coefficients provides a trade off between CR and image quality.

3-Using DCT by segmenting each line into vectors may result in blocking artifacts. These artifacts are perceptually annoying and become prominent in the reconstructed images at very low bit-rates.

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Table (1): Objective Results for interlaced Saturn image.

Number of selected column /vector	Compression ratio	Bit per pixel (bpp)	PSNR (db)
64 column	6.4	1.25	36.2834
51 column	8.0314	0.9961	35.6303
39 column	10.5026	0.7617	34.6501
32 column	12.8	0.625	33.6895

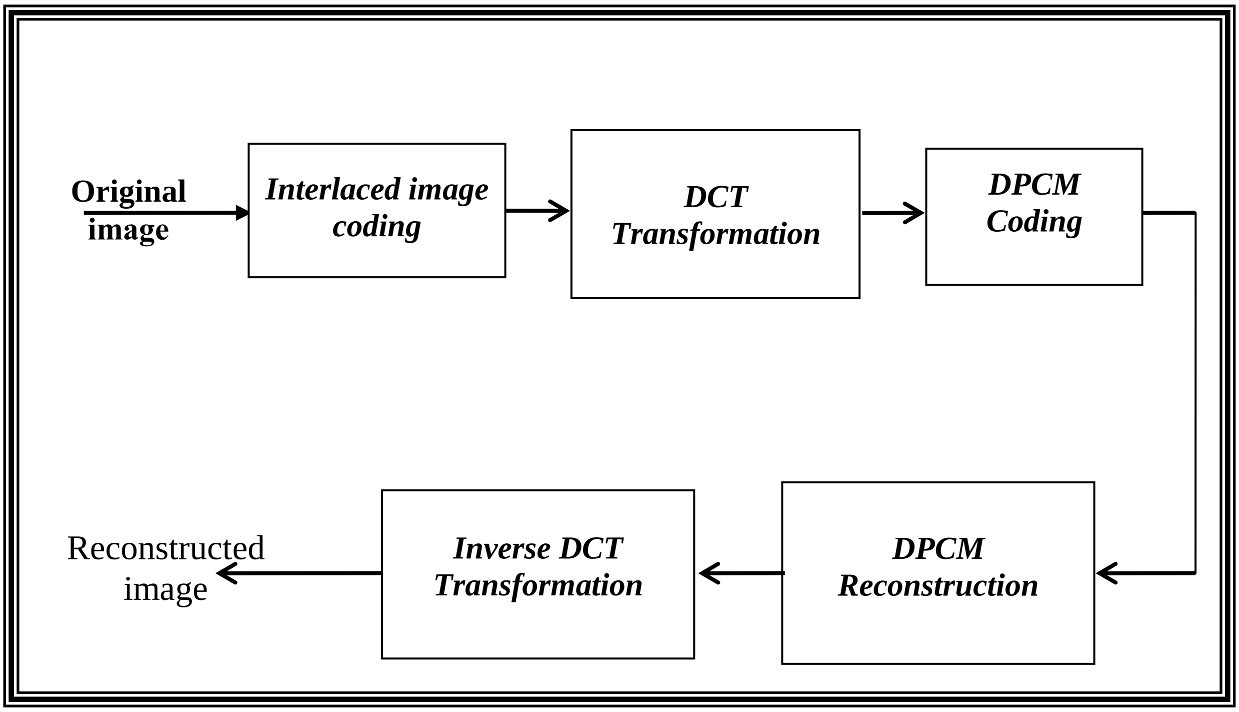

Fig. (1) Block diagram of the interlaced hybrid (DCT/DPCM) system.

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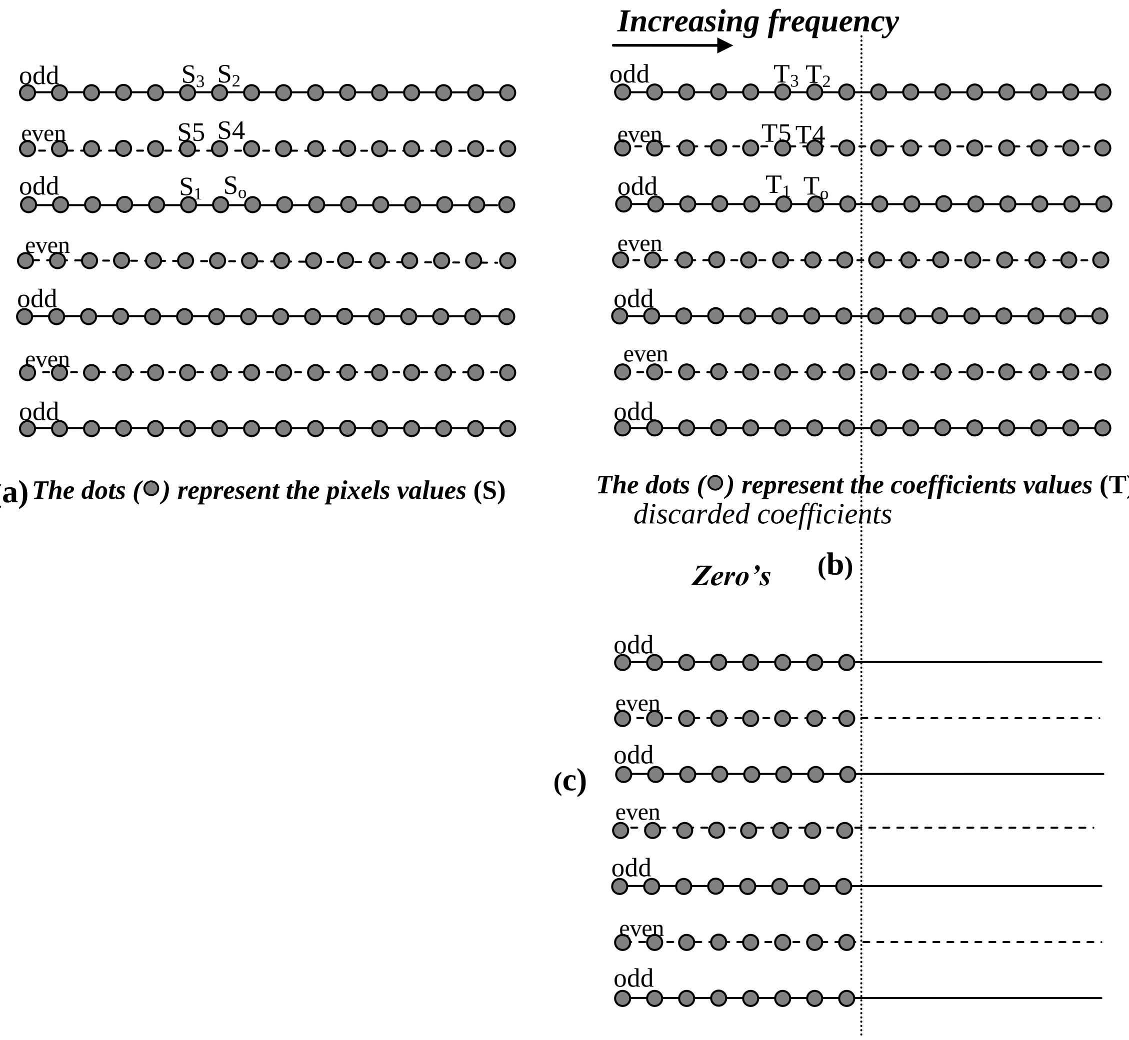
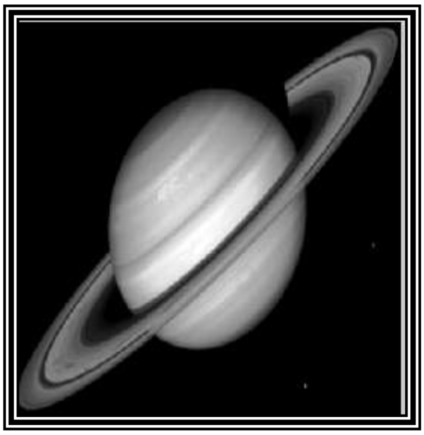


(a) ***The dots (●) represent the pixels values* (S)**

***The dots (●) represent the coefficients values* (T)**

(b)

(c)



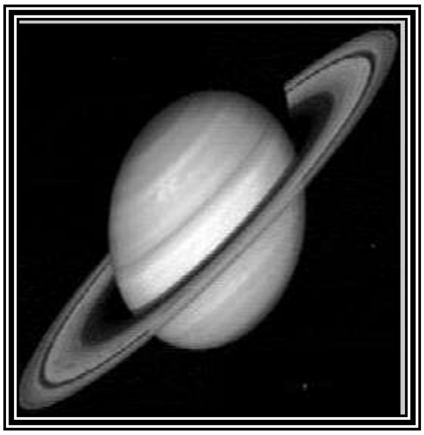


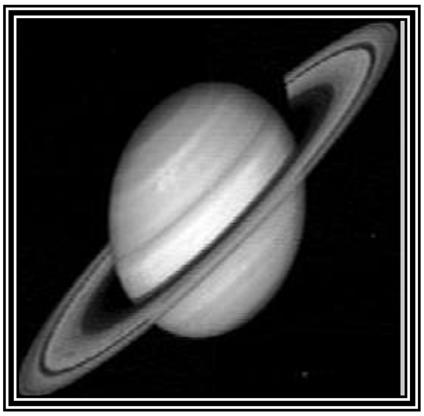
Fig. (2) Procedures applied to each (row vector) of the *interlaced* image

(a) The original interlaced image.

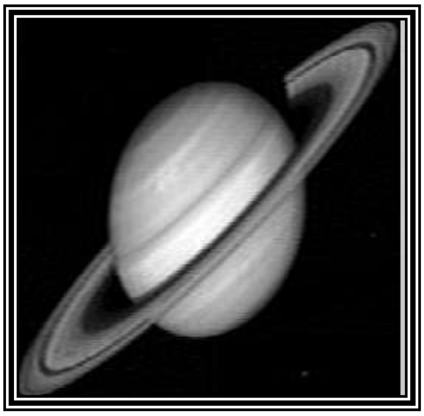
(b) 1D Transformed image.

(c) Transformed coefficients after discarded high frequency coefficients.

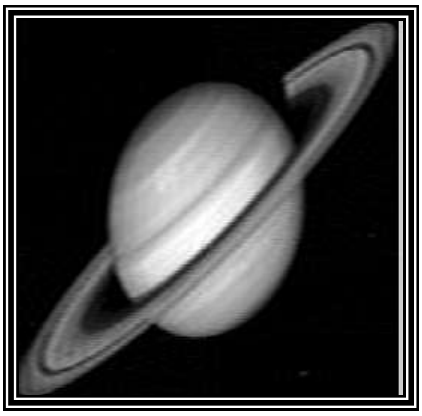
(a) (b)



(c)



(d)



(e)

Fig. (3) Interlaced hybrid DCT/DPCM of Saturn image.

(a) Original image with (8bpp).

(b) Reconstructed image with 64 columns/block (1.25 bpp).

(c) Reconstructed image with 51 columns/block (0.9961bpp).

الترميز ألهجينيDCT/DPCM في ضغط الصور المتشابكة

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الخلاصة

من خلال طبيعة الصور، تكون عناصر الصورة في مناطق محددة مترابطة بشكل كبير مع بعضها البعض. في هذه الحالات، عمليات ضغط الصور تستخدم لتقليل كمية المعطيات المطلوبة لتمثيل نفس المعلومات إما بصورة تامة أو تقريبية. تم تصميم وتنفيذ نظام هجيني لضغط الصور المتشابكة. يتم تحويل إشارة الصورة باتجاه الصف باستخدام محول الجيب المنفصل ثم يستخدم التمثيل الرمزي التفاضلي الرقمي باتجاه العمود للحصول على إشارة الفرق .بالنسبة للصور الساكنة تم استخدام مكمم عددي أما للصور المتشابكة فقد تم استخدام نفس المكمم العددي للمجال الفردي و مكمم عددي اقل للمجال الزوجي لان إشارة الفرق للمجال الزوجي كانت صغيرة جداً، أعطت القياسات العملية قيمة عالية لنسبة الإشارة إلى الضوضاء(PSNR) بدون أي تشوه ملحوظ.

الكلمات ألدالة: المتشابكة، ضغط الصور الهجين، الترميز ألهجيني DCT/DPCM، طرح الفائض.