Double Transform Contour Compression

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ABSTRACT

In this paper a data compression technique using double transforms is proposed. The compression ability of any transform or a combination of transforms is evaluated by the error in the reconstructed data and/or its fast implementation. This investigation concerns the reduction in the computational requirements for data compression without increasing, significantly, the error in reconstruction. The double transform approach is based on the transformation of input data using WHT, rejecting some of the spectral components, converting the spectrum from WHT domain into DCT domain, and then inverse transform using DCT. In the experimental part of this paper, several contours extracted from 2D images, using the FCCE method for contour extraction, ware used. It is shown that the proposed technique reduces the number of multiplication operations, comparing with DCT. In addition, the compression process does not require any multiplications at the transmitting end, thus can be used for real time compression applications.

1. INTRODUCTION

In this investigation a data compression technique using double transforms is proposed. The analysis of the contour data compression using the zonal sample reduction scheme is presented. The performances of the Walsh-Hadamard Transform (WHT), Discrete Cosine Transform (DCT), and the proposed Walsh-Cosine double transform, are compared using the data of several contours.

WHT has good performance with respect to its fast implementation. The WHT does not require any multiplication operations for transforming input data from spatial domain into the spectral domain[1]. DCT is known for its good performance in data compression applications, comparing with other transforms such as Discrete Sine Transform (DST), Haar, and WHT transforms[2,3].This has led to the development of many algorithms for the fast computation of DCT transform[4].

Transform data compression can be achieved using either threshold sampling or zonal sampling schemes[5]. In threshold sampling, the transform domain samples which are above a certain level are selected. The zonal sampling selects the transform domain samples that are

located in a predetermined zone, and the rest are set to zero. Data compression using threshold sampling scheme requires the position of the selected samples as an over-head information.

The compression ability of any transform or a combination of transforms is evaluated with respect to the error in the reconstructed data and/or the computational requirements. Ramaswamy and Mikheal, in [6], have developed an image compression technique using mixed transforms. In this technique the image is represented employing subsets of basis functions of two transforms. The image is reconstructed at the encoder and the residual error is also transmitted using a lossless technique. This received error is then added to the reconstructed image at the receiving end. This approach yields better compression than the DCT transform alone at the cost of increased computational requirements.

In section 2, two approached to data compression using the zonal samples reduction are investigated. The reconstructed data, using the first approach, has the same number of samples as the input data. Using the second approach, the reconstructed data has a reduced number of samples. In section 3, the procedure for the double transform technique is presented, and the advantages of using this technique are illustrated. In section 4, a more general results are obtained, using the data of several contours as the input to the presented technique of data compression. Section 5, concludes the paper.

2. DATA COMPRESSION USING ZONAL SAMPLING SCHEME

In this section two approaches are investigated. The first approach, retain the first M spectral coefficient and set the rest to zero. The number of retained spectral coefficients is calculated as follows :

$$M = Round(N/n) \tag{1}$$

where n is the coefficients retained factor.
     N is the number of data samples.

In the second approach, the first M spectral coefficient are retained and the rest are discarded, to form a spectrum with only (M) coefficients. Using this approach, the reconstructed signal has a reduced number of samples.
For both approaches of zonal sampling, the forward transformation is as follows :

$$[S(N)] = [T(N)] [X(N)] \tag{2}$$

The inverse transform, for the first approach of zonal sampling, is obtained by :

$$[S'(N)] = \begin{cases} s_i & \text{for } i = 0 \text{ to } M\text{ - }1 \\ 0 & \text{for } i = M \text{ to } N\text{ - }1 \end{cases} \tag{3}$$

$$[X'(N)] = [IT(N)] [S'(N)] \tag{4}$$

and for the second approach

$$[S(M)] = s_i \qquad \text{for } i = 0 \text{ to M-1} \tag{5}$$

$$[X'(M)] = [IT(M)] [S(M)] \tag{6}$$

where [X(N)] is the input data.
    [X'(N)] is the reconstructed data.
    [X'(M)] is the reconstructed data with reduced number of samples.
    [S(N)] is the spectrum of coefficients.
    [S'(N)] is the spectrum of coefficients with only (M) nonzero components.

[S(M)]   is the spectrum of coefficients with only (M) components.
[T(N)]   is the forward transform matrix.
[IT(N)] is the inverse transform matrix.

To compare the performance of WHT and DCT the x and y co-ordinates of the contour shown in Fig.1a are used as the input data. The reconstructed contours, with the same number of samples, are shown in Fig.1b and Fig.1c for the WHT and DCT respectively. These results are obtained with compression rate of 16:1. It can be seen that the performance of the DCT is much better than that of WHT. Fig.1d and Fig.1e show the reconstructed contours, with the reduced number of samples, for the WHT and DCT respectively. These results are obtained with the same compression rate used by the first approach, i.e. 16:1. It can be seen that the performance of the DCT is more or less the same as that obtained by WHT.

(a)

(b)   (c)   (d)   (e)
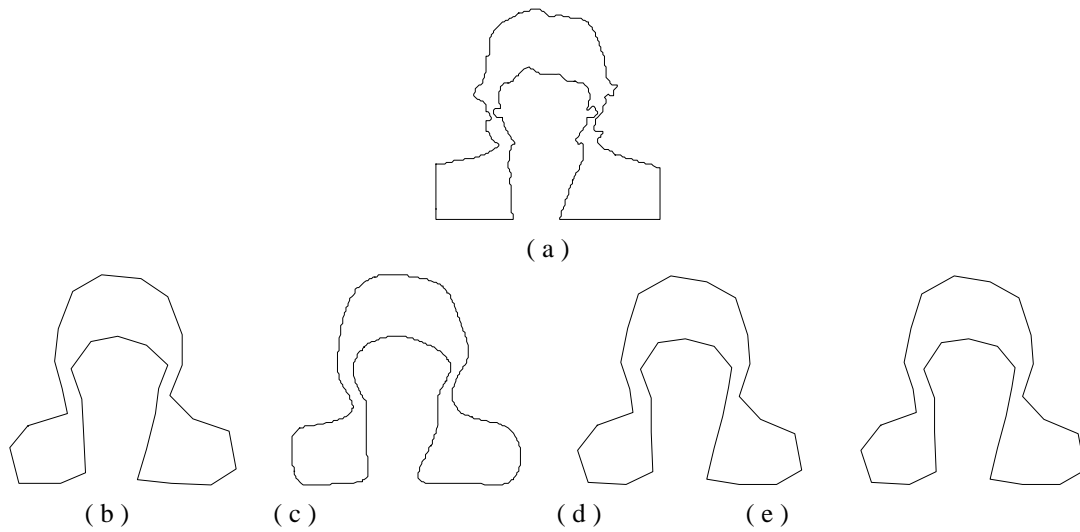
a- Original contour.
b- Reconstructed contour with MSE =16.186 using WHT by the first approach of zonal compression.
c- Reconstructed contour with MSE = 1.658 using DCT by the first approach of zonal compression.
d- Reconstructed contour with MSE =40.843 using WHT by the second approach of zonal compression.
e- Reconstructed contour with MSE =40.528 using WHT by the second approach of zonal compression.

Fig.1 a: Original contour, and c-e: Reconstructed contours using 16:1 compression rate.

3. DOUBLE TRANSFORMS IMPLEMENTATION

The double transforms technique is implemented using the following three steps
step 1 : Forward transformation. Transform the input data using WHT, and select the first M
      spectral coefficients for transmission or storage.
step 2 : Spectrum conversion. Inverse transform the WHT spectrum, and then forward
      transform using DCT.
step 3 : Data reconstruction. Append the DCT spectrum with (N-M) zeros, then inverse
      transform to obtain the reconstructed data.

The reconstructed contours of Fig.1a, with a compression rate of 93.75 %, i.e. 16:1, using the WHT, DCT, and the proposed double transformation Wal-Cos, are shown in Fig.2.a-c respectively together with the MSE obtained by each of them.
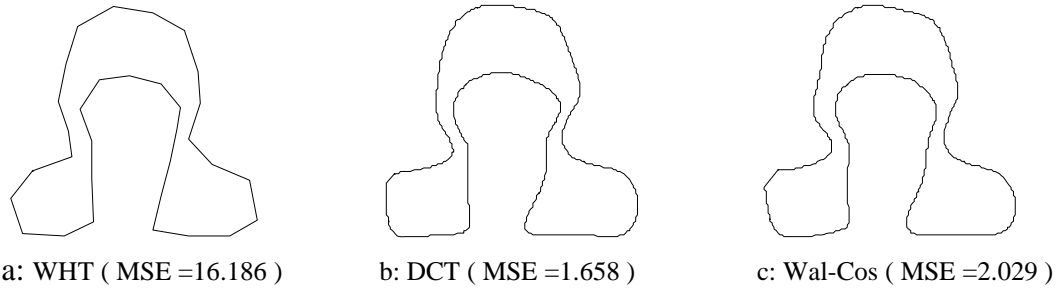
a: WHT (MSE =16.186)　　　b: DCT (MSE =1.658)　　　c: Wal-Cos (MSE =2.029)

**Fig.2　Reconstructed contour using WHT, DCT, and Wal-Cos double transform,
and compression rate of 16:1.**

The block diagram in Fig.3 shows how the Walsh-Cosine double transform procedure is arranged with respect to the transmitting and receiving ends of the data compression system. The block diagram shows that, at the transmission end of the data compression only WHT is used, i.e. no multiplication operations are required, and all spectral coefficients are integers for an integer input data. The total number of multiplication operations is reduced by a factor proportional to the compression rate.
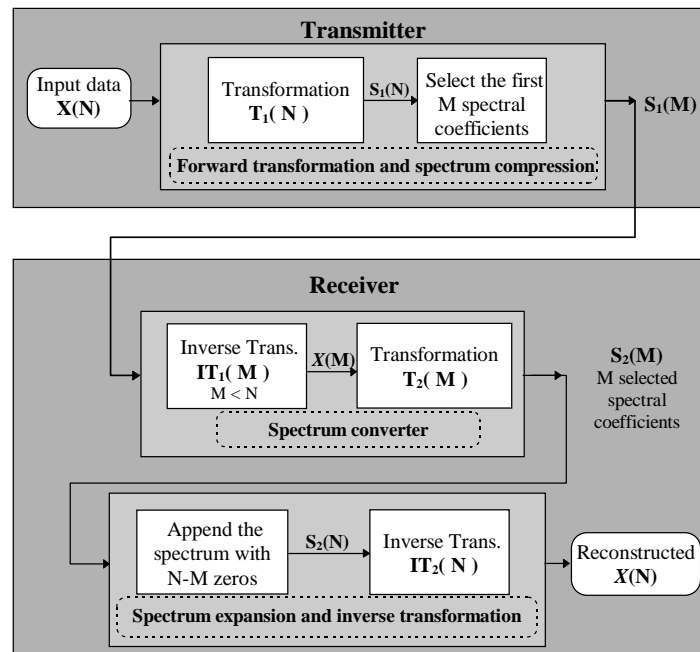
where :

X(N)	is an N samples input data.
X(N)	is an N samples reconstructed data.
X(M)	is an reduced size (M samples) reconstructed data.
T_1, IT_1	are the forward and the inverse Walsh transform matrices.
T_2, IT_2	are the forward and the inverse Cosine transform matrices.
$S_1(N), S_1(M)$	are the normal and compressed Walsh spectrums respectively.
$S_2(M), S_2(N)$	are the normal and expanded Cosine spectrums respectively.

Fig.3　Double transform data compression.

4. EXPERIMENTAL RESULTS

Contours extracted from their original images, shown in Fig.4, were used to test the proposed technique. The algorithm given in [7] is used for the extraction of the contours.
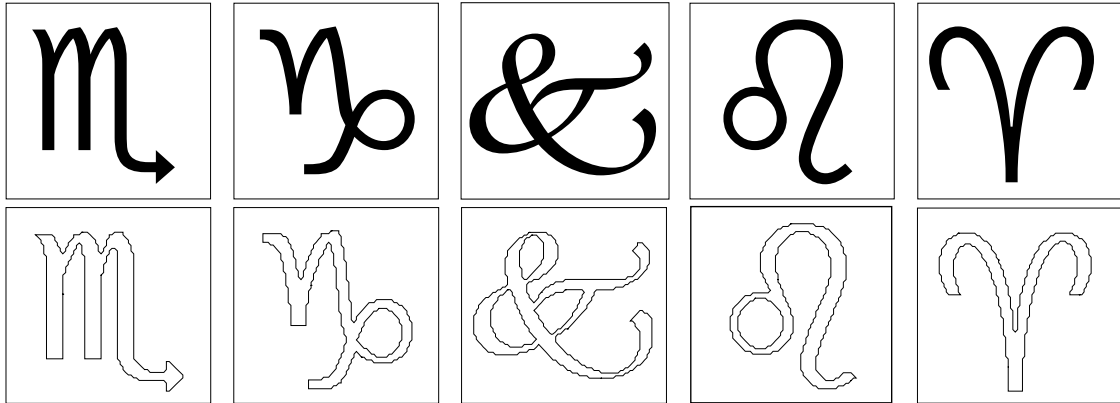

Fig.4 TOP: original images (80x80 pixels), BOTTOM: extracted contours using FCCE algorithm.

Fig.5. shows the average MSE for reconstructing the contours of the five images of Fig.4., using DCT, WHT, and Walsh-Cosine double transform. Different compression rates are used, 2:1, 4:1, 8:1, and 16:1. It can be seen that Walsh-Cosine double transform give MSE close to that obtained using DCT transform with zonal compression, and also reduce the total number of multiplication operations comparing with the DCT transform. Because the Walsh transform does not require any multiplications. The percentage reduction in multiplication operations versus compression rates is shown in Fig.6. These results are true using any of the fast algorithms for DCT [3].
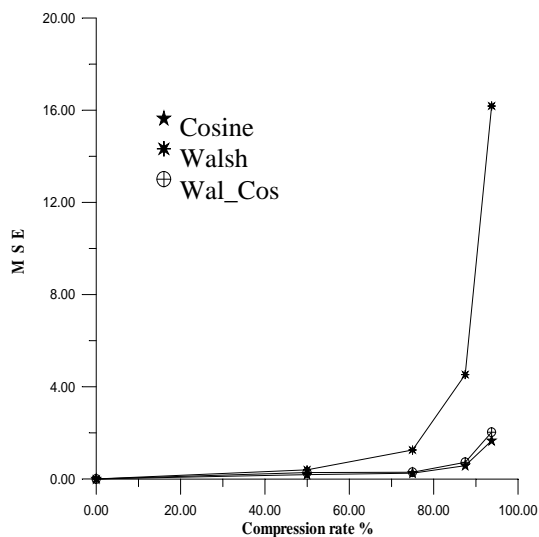

**Fig.5. MSE v compression rate for
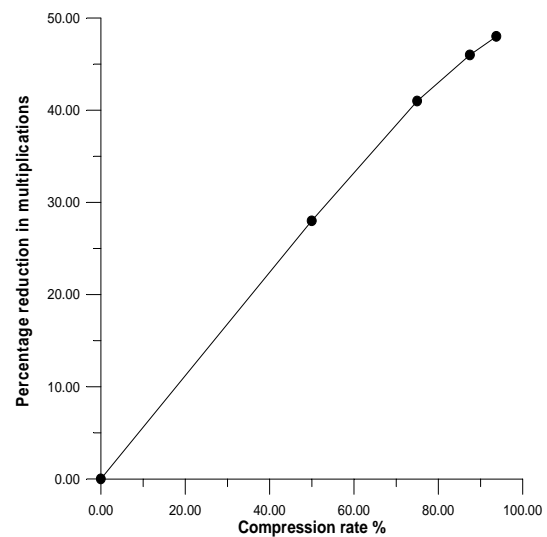DCT, WHT, and Wal-Cos transformation.**

**Fig.6. Reduction in multiplications
versus compression rate.**

5. CONCLUSIONS

The obtained results show that the Walsh-Cosine double transform has the advantage of reconstructing the input data with MSE very close to that obtained using DCT, and with reduced number of multiplication operations. In addition, all spectrum elements are integers for an integer input data, and no multiplications are required at the transmitting end. In general the proposed scheme of data compression can be efficiently used for real time compression applications.

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