A Novel Transform for Image Compression

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***Abstract*—In this paper, we propose an orthogonal multiplication-free transform of order that is an integral power of two by an appropriate extension of the well-known fourth-order integer discrete cosine transform. Moreover, we develop an efficient algorithm for its fast computation. It is shown that the computational and structural complexities of the algorithm are similar to that of the Hadamard transform. By applying the proposed transform to image compression, we show that it outperforms the existing transforms having complexities similar to that of the proposed one.**

***Index Terms*—Multiplication-free transform, approximate DCT, Hadamard transform, image compression.**

I. INTRODUCTION

The floating-point discrete cosine transform (DCT), which is well-known in image compression [1]-[4], can not meet the requirement of very fast compression in many applications of recent mobile and communication systems. Therefore, a faster transform having a good compromise between the computational complexity and energy compaction capability is desired.

To this end, there has been a huge interest in developing integer and multiplication-free transforms [5]-[8]. Among these transforms, the signed DCT (SDCT) is interesting because it can easily be obtained from the DCT [5]. However, the SDCT of order $N \geq 16$ is not orthogonal and its inverse requires additions and multiplications. Moreover, its performance in image compression is still very low. In order to improve the performance of the SDCT for the case of $N = 8$, an 8×8 multiplication-free transform has been proposed in [6]. Even though the transform in [6] has a low complexity its performance in image compression is still lower than that of the approximated DCT reported in [7]. In addition, the transforms in [6] and [7] are useful only for the case of $N = 8$. In this paper, a more effective transform for any order that is an integral power of two is proposed by an appropriate extension of the well-known fourth-order integer discrete cosine transform.

II. PROPOSED TRANSFORM

In this section, we propose a multiplication-free transform of order $N > 4$ suitable for image compression by an appropriate extension of the well-known fourth-order integer DCT presented by Fig. 1. We also develop an efficient algorithm for fast computation of the proposed transform. Due to the lack of space, the mathematical development of the transform and its algorithm is omitted in this paper. We include only the structures of the transform for $N = 8$, 16 and 32 given by Figs. 2, 3 and 4, respectively. It is easy to obtain the transform matrices of orders 8, 16 and 32 from these structures. For example, the proposed transform matrix of order 8 whose structure presented by Fig.2 is given as

$$\mathbf{T}_8 = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 2 & 1 & -1 & -2 & -2 & -1 & 1 & 2 \\ 2 & 1 & -1 & -2 & 2 & 1 & -1 & -2 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \\ 1 & -2 & 2 & -1 & -1 & 2 & -2 & 1 \\ 1 & -2 & 2 & -1 & 1 & -2 & 2 & -1 \end{bmatrix}$$

It is clear from these structures that the proposed transform requires 24 additions and 4 bit-shifts, 64 additions and 8 bit-shifts, and 160 additions and 16 bit-shifts to transform sequences of orders 8, 16 and 32, respectively. This complexity equals that required by the Hadamard transform, except that this latter does not require the bit-shift operations.

III. APPLICATION TO IMAGE COMRESSION

In this section, we apply the proposed transform to image compression and show that it outperforms the existing transforms having complexities similar to that of the proposed one. For this purpose, we consider the experiment used in [5], [6] and carry out a simulation of the JPEG technique for $N = 8$ by employing the SDCT matrix in [5], approximated DCT matrix $\hat{\mathrm{D}}_1$ in [7], scaled DCT matrix in [8], and proposed transform matrix. Note that the scaled DCT [8] is employed only for the sake of reference. The block size

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used to scan the image is 8×8. Fig. 5 shows the PSNR obtained for 512×512 "Lena" image using different transforms in terms of the number of transform coefficients employed to reconstruct the image. It is clear from this figure that the performance of the proposed transform is better than that of the approximated DCT [7] when the number of retained transform coefficients is greater than 10.

It should be noted that the only existing transform having a complexity similar to that of the proposed transform for the case of $N = 16$ is the Hadamard transform. The SDCT of order $N \geq 16$ is not orthogonal and its inverse requires additions and multiplications. For this reason, we carry out a simulation for the case of $N = 16$ by employing only the Hadamard matrix and the proposed matrix. For the sake of reference, the corresponding results are also included for the scaled DCT [8].The block size used to scan the image in this case is 16×16. Fig. 6 shows the PSNR obtained for 512×512 "Lena" image using different transforms in terms of the number of transform coefficients employed to reconstruct the image. It is clear from this figure that the performance of the proposed transform is significantly superior to that of the Hadamard transform. Note that the Figs. 5 and 6 are presented before Figs. 1-4 in order to save space.

IV. Conclusion

In this work, an orthogonal multiplication-free transform of order that is an integral power of two has been proposed by an appropriate extension of the well-known fourth-order integer discrete cosine transform. An efficient algorithm for its fast computation has also been developed and shown to have computational and structural complexities similar to that of the Hadamard transform. We have applied the proposed transform to image compression and the simulation results show that the performance of the proposed transform is better than that of the existing transforms having complexities similar to that of the proposed one.

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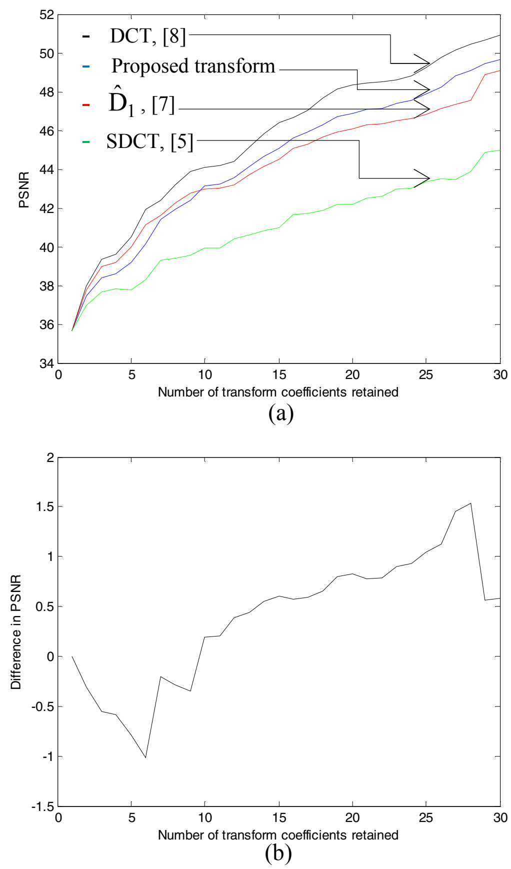

Fig. 5. (a) PSNR obtained by different transforms of order $N = 8$ for Lena image, (b) difference between the PSNR obtained by the proposed transform and that obtained by the transform in [7].

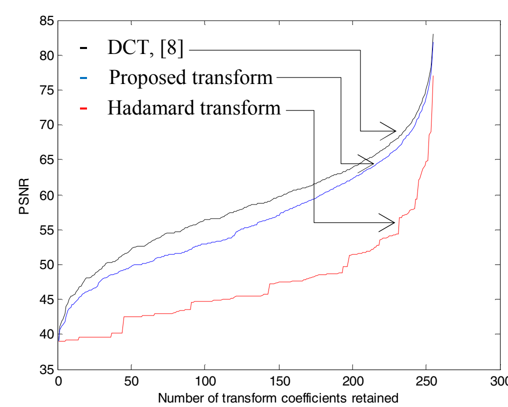

Fig. 6. PSNR obtained by different transforms of order $N = 16$ for Lena image,

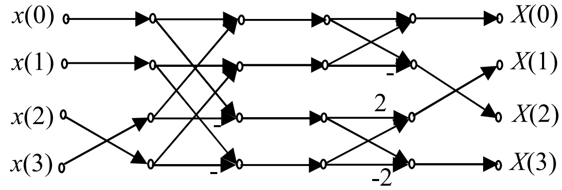

Fig. 1. Integer DCT of order N=4.

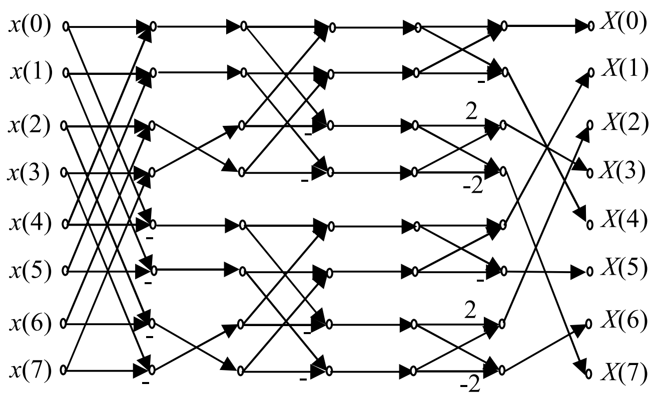

Fig. 2. Fast algorithm for the proposed transform of order N=8.

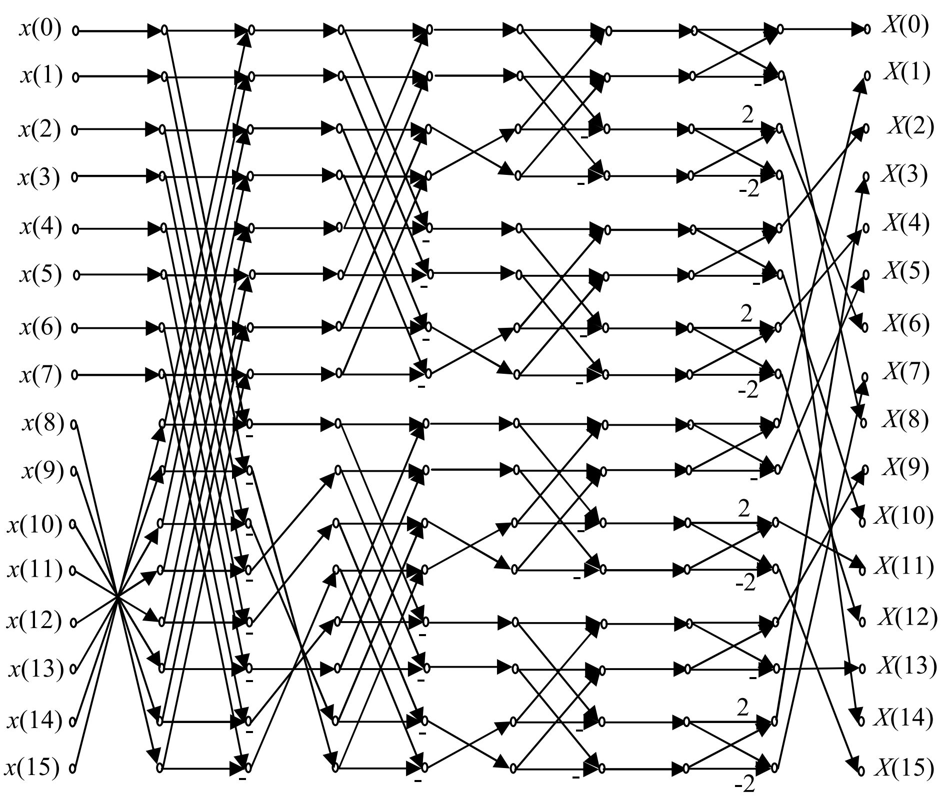

Fig. 3. Fast algorithm for the proposed transform of order N=16.

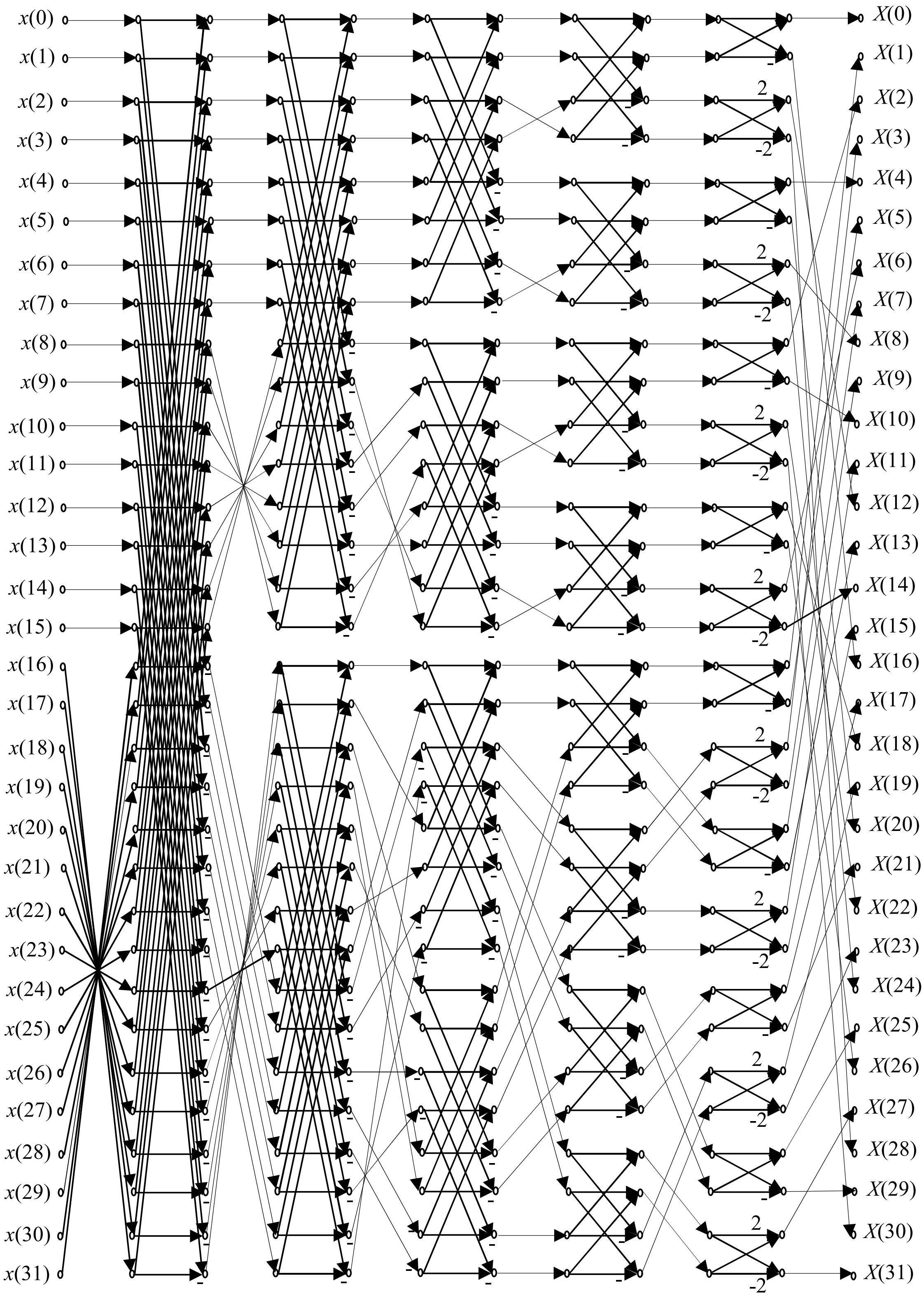

Fig. 4. Fast algorithm for the proposed transform of order N=32.