Review Paper on 8-point Approximate DCT for Image Compression

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ABSTRACT
The multiplier free approximate DCT transform is proposed. The transform offers superior compression performance at very low circuit complexity. Such approximations can be realized in digital VLSI hardware using additions and subtractions only, leading to significant reductions in chip area and power consumption compared to conventional DCTs and integer transforms. The proposed transform requires only 14 addition operations and no multiplications.

Keywords
Image Compression, DCT

1. INTRODUCTION
Image compression is essential for many applications such as multimedia, internet and mobile communication. Transform-based compression techniques are widely used in such applications. The discrete cosine transform (DCT) is an essential mathematical tool in both image and video coding. DCT is widely adopted in several image and video coding standards such as JPEG, MPEG-1,MPEG-2, H.261, and H.263. This is mainly due to its good energy compaction properties.

The several efficient algorithms were developed for fast computation of DCT. As fast algorithms can significantly reduce the computational complexity of computing the DCT, floating-point operations are still required. The floating-point operations are expensive in terms of circuitry complexity and power consumption. Therefore, minimizing the number of floating-point operations is required in a fast algorithm. The solution to this problem is use of approximate transforms.

The paper introduces a new DCT approximation that possesses an extremely low arithmetic complexity, requiring only 14 additions. The DCT approximation methods under consideration are the Cintra -Bayer (CB) approximate DCT, the modified CB approximate DCT.

2. PREVIOUS WORK
Some DCT approximations can totally eliminate the requirement for floating-point operations. All calculations are performed over a fixed-point arithmetic framework. In general, these approximation methods employ a transformation matrix whose elements are defined over the set {0,±1/2,±1,±2}. This implies null multiplicative complexity, because the required operations can be implemented exclusively by means of binary additions and shift operations. Such DCT approximations can provide low-cost and low- power designs and effectively replace the exact DCT and other DCT-like transforms. Indeed, the performance characteristics of the low complexity DCT approximations appear similar to the exact DCT, while their associate hardware implementations are economical because of the absence of multipliers.

The different DCT approximate methods are explained in terms of its transformation matrices and the associated fast algorithms obtained by matrix factorization techniques.

1. CB-2011 Approximation
By rounding-off the elements of the exact DCT matrix, CB-2011 Approximation [3] is obtained. The transformation matrix is given as

$C_2 = D_2 \cdot T_2$

$$= D_2 \cdot \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 0 & 0 & -1 & -1 & -1 \\ 1 & 0 & 0 & -1 & -1 & 0 & 0 & 1 \\ 1 & 0 & -1 & -1 & 1 & 1 & 0 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & -1 & 0 & 1 & -1 & 0 & 1 & -1 \\ 0 & -1 & 1 & 0 & 0 & 1 & -1 & 0 \\ 0 & -1 & 1 & -1 & 1 & -1 & 1 & 0 \end{bmatrix}$$

Where D2=diag $(1/\sqrt{8},1/\sqrt{6},1/2,1/\sqrt{6},1/\sqrt{8},1/\sqrt{6},1/2,1/\sqrt{6})$ and

$T_2 = P_2 \cdot A_6 \cdot A_5 \cdot A_1$

$$A_5 = \mathrm{diag}\left(\begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 \\ 0 & 1 & -1 & 0 \\ 1 & 0 & 0 & -1 \end{bmatrix} \cdot \begin{bmatrix} -1 & 1 & -1 & 0 \\ -1 & -1 & 0 & 1 \\ 1 & 0 & -1 & 1 \\ 0 & 1 & 1 & 1 \end{bmatrix} \right)$$

$$A_6 = \mathrm{diag}\left(\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}, -1, I_5 \right)$$

Matrix P_2 has permutation: (1)(2 5 8)(3 7 6 4).

2. Modified CB-2011 Approximation
This transform is obtained by replacing elements of the CB-2011 matrix with zeros [5].The transformation matrix is given as

$C_3 = D_3 \cdot T_3$

$$= D_3 \cdot \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\ 1 & 0 & 0 & -1 & -1 & 0 & 0 & 1 \\ 0 & 0 & -1 & 0 & 0 & 1 & 0 & 0 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 0 & -1 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & -1 & 1 & 0 & 0 & 1 & -1 & 0 \\ 0 & 0 & 0 & -1 & 1 & 0 & 0 & 0 \end{bmatrix}$$

Where $D_3 = \mathrm{diag}\,(1/\sqrt{8},1/\sqrt{2},1/2,1\sqrt{2},1/\sqrt{8},1/\sqrt{2},1/2,1/\sqrt{2})$.

The matrix $T_3 = P_2 \cdot A_6 \cdot A_7 \cdot A_1$

$$A_7 = \text{diag}\left(\begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 \\ 0 & 1 & -1 & 0 \\ 1 & 0 & 0 & -1 \end{bmatrix}, -I_3, \ 1 \right)$$

3. Approximate DCT

The transformation matrix for the approximate DCT in [6] is given as

$C_4 = D_4 \cdot T_4$

$$= D_4 \cdot \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 2 & 1 & 1 & 0 & 0 & -1 & -1 & -2 \\ 2 & 1 & -1 & -2 & -2 & -1 & 1 & 2 \\ 1 & 0 & -2 & -1 & 1 & 2 & 0 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & -2 & 0 & 1 & -1 & 0 & 2 & -1 \\ 1 & -2 & 2 & -1 & -1 & 2 & -2 & 1 \\ 0 & -1 & 1 & -2 & 2 & -1 & 1 & 0 \end{bmatrix}$$

Where $D_4 = 1/2 \cdot \text{diag}\,(1/\sqrt{2}, 1/\sqrt{3}, 1/\sqrt{5}, 1/\sqrt{3}, 1/\sqrt{2}, 1/\sqrt{3}, 1/\sqrt{5}, 1/\sqrt{3})$ and

$T_4 = P_3 \cdot A_9 \cdot A_8 \cdot A_1$ where

$$A_9 = \text{diag}\left(\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}, \begin{bmatrix} 1 & 2 \\ -2 & 1 \end{bmatrix}, I_4 \right)$$

$$A_8 = \text{diag}\left(\begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 \\ 0 & 1 & -1 & 0 \\ 1 & 0 & 0 & -1 \end{bmatrix}, \begin{bmatrix} 0 & 1 & 1 & 2 \\ -1 & -2 & 0 & 1 \\ 1 & 0 & -2 & 1 \\ -2 & 1 & -1 & 0 \end{bmatrix} \right)$$

Matrix P_3 has the permutation (1)(2 5)(3)(4 7 6)(8).

3. PROPOSED TRANSFORM

The transformation matrix for 8 point DCT approximation has following format,

[diagonal matrix] × [low complexity matrix]

The diagonal matrix usually contains irrational numbers in the form $1/\sqrt{m}$, where m is a small positive integer. The irrational numbers required in the diagonal matrix would require an increased computational complexity. However, in the context of image compression, the diagonal matrix can simply be absorbed into the quantization step of JPEG-like compression procedures. Therefore, in this case, the complexity of the approximation is bounded by the complexity of the low-complexity matrix. Since the entries of the low complexity matrix comprise only powers of two in $\{0,\pm1/2,\pm1,\pm2\}$ so that null multiplicative complexity is achieved.

The aim is to derive low-complexity approximate DCT. For this, a candidate matrix is find that possess low computation cost. The cost of a transformation matrix is defined as the number of arithmetic operations required for its computation. The good candidates matrix has entries such that it do not require multiplication operations. Thus we have the following optimization problem:

$T^* = \arg\min \text{cost}(T)$

Where T^* is the sought matrix and returns the arithmetic complexity of T . Additionally, the following constraints were adopted:

1) Elements of matrix must be in $\{0,\pm1,\pm2\}$ to ensure that resulting multiplicative complexity is null.

2) All rows of T are non-null.

3) Matrix $T \cdot T^T$ must be a diagonal matrix to ensure orthogonality of the resulting approximation.

An important parameter in the image compression routine is the number of retained coefficients in the transform domain. In several applications, the number of retained coefficients is very low. For considering 8× 8 image blocks, in image compression using support vector machine, only the first 8–16 coefficients were considered. We adopted the number of retained coefficients equal to 10. The following DCT approximation is proposed.

$C = D \cdot T$

$$= D \cdot \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 0 & 0 & 0 & 0 & -1 & 0 \\ 1 & 0 & 0 & -1 & -1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 \\ 0 & -1 & 1 & 0 & 0 & 1 & -1 & 0 \\ 0 & 0 & 1 & 0 & 0 & -1 & 0 & 0 \end{bmatrix}$$

Where $D = \text{diag}\{1/\sqrt{8}, 1/\sqrt{2}, 1/2, 1/\sqrt{2}, 1/\sqrt{8}, 1/\sqrt{2}, 1/2, 1/\sqrt{2}\}$

Matrix T^* has entries in $\{0,\pm1\}$ and it can be given a sparse factorization according to:

$T = P4 \cdot A12 \cdot A11 \cdot A1$

Where

$$A_{11} = \text{diag}\left(\begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 \\ 0 & 1 & -1 & 0 \\ 1 & 0 & 0 & -1 \end{bmatrix}, I_4 \right)$$

$$A_{12} = \text{diag}\left(\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}, -1, I_5 \right)$$

And P_4 is the permutation (1)(2 5 6 8 4 3 7).

4. CONCLUSION

The 8-point approximate DCT method is proposed for image compression. The advantage of using this method is that it gives low computational complexity in terms of algorithm complexity. Also the proposed DCT approximation is a candidate for reconfigurable video standards such as HEVC.

5. REFERENCES

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