Hybrid DCT/DFT/Wavelet Architecture Based on Jacket Matrix

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진 주, 이 문 호
Zhu Chen, Moon Ho Lee

Abstract – We address a new representation of DCT/DFT/Wavelet matrices via one hybrid architecture. Based on an element inverse matrix factorization algorithm, we show that the DCT, DFT and Wavelet which based on Haar matrix have the similarrecursive computational pattern, all of them can be decomposed to one orthogonal character matrix and a special sparse matrix. The special sparse matrix belongs to Jacket matrix, whose inverse can be from element-wise inverse or block-wise inverse. Based on this trait, we can develop a hybrid architecture.

Key Words : DCT, DFT, Wavelet, Jacket Matrix, Element-wise, Inverse Sparse Matrix

1. Introduction

Discrete Cosine Transform (DCT) has found applications in signal classification and representation [1]. The DCT-II is a popular structure and it is usually accepted as the best suboptimal transformation that its performance is very close to that of the statistically optimal Karhunen-Loeve transform [2].The discrete Fourier transform (DFT) is a popular transformation for signal processing and communication [3]. Furthermore, the discrete wavelet transform based on the Haar matrix (HWT) is also very useful in image compression and signal analysis. To analyze these three different transforms, we now focus on the sparse matrix factorization based on Jacket matrix.

Otherwise, the analysis and decomposition of the sparse matrix demonstrated as a useful tool to develop the fast computations and character generalization. Therefore, similar to the method in [4], the DCT-II and DFT, HWT matrices can be decomposed to one orthogonal character matrix and a special sparse matrix. The inverse of the sparse matrix is from element-wise inverse or block-wise inverse. Mathematically, let $A=(a_{ij})$be a matrix, if$A^{-1}=(a_{ij}^{-1})^T$, then the matrix A is a Jacket matrix. Obviously the special sparse matrix belongs to Jacket matrix. Here, we name the special Jacket matrix as element inverse sparse matrix. In this paper, we focus on the architecture of the sparse matrix decomposition and propose a hybrid architecture to joint the DCT and HWT together. The same architecture to combine DCT and DFT has been introduced in [5].

2. BLOCK-WISE Inverse sparse matrix Decomposition for DCT-II Matrix

Thus the DCT-II matrix can be written by

$$[C]_N=([P_r]_N)^{-1}\begin{bmatrix} I_{\frac{N}{2}} & 0 \\ 0 & K_{\frac{N}{2}} \end{bmatrix}\begin{bmatrix} C_{\frac{N}{2}} & 0 \\ 0 & C_{\frac{N}{2}} \end{bmatrix}\begin{bmatrix} I_{\frac{N}{2}} & 0 \\ 0 & D_{\frac{N}{2}} \end{bmatrix}\begin{bmatrix} I_{\frac{N}{2}} & I_{\frac{N}{2}} \\ I_{\frac{N}{2}} & -I_{\frac{N}{2}} \end{bmatrix}([P_c]_N)^{-1} \quad (1)$$

The butterfly data flow diagram is shown as in Fig.1.

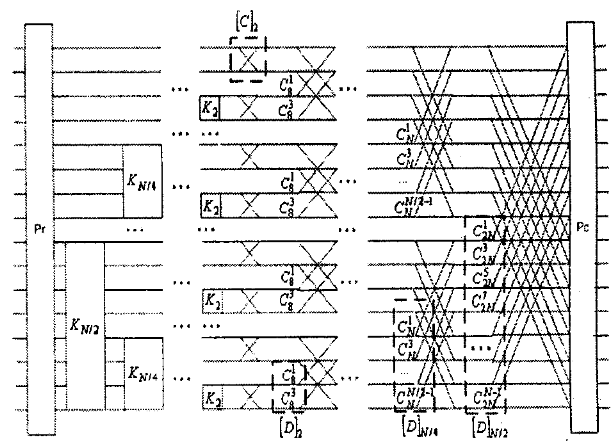

Fig.1 Butterfly data flow diagram of the proposed computation of the N-by-N DCT-II matrix

3. Element-wiseInverse Sparse Matrix Decomposition for DFT matrix

We can rewrite the permuted DFT matrix by using

*Zhu Chen is with the Institute of Information & Communication, Chonbuk National University, Chonju, 561-756,Korea. (e-mail: chenzhu@chonbuk.ac.kr)
**Moon Ho Lee is with the Institute of Information & Communication, Chonbuk National University, Chonju, 561-756,Korea.(e-mail: moonho@chonbuk.ac.kr)

$$[\tilde{F}]_N = \begin{bmatrix} I_{\frac{N}{2}} & 0 \\ 0 & \Pr_{\frac{N}{2}} \end{bmatrix} \begin{bmatrix} \tilde{F}_{\frac{N}{2}} & 0 \\ 0 & \tilde{F}_{\frac{N}{2}} \end{bmatrix} \begin{bmatrix} I_{\frac{N}{2}} & 0 \\ 0 & W_{\frac{N}{2}} \end{bmatrix} \begin{bmatrix} I_{\frac{N}{2}} & I_{\frac{N}{2}} \\ I_{\frac{N}{2}} & -I_{\frac{N}{2}} \end{bmatrix} \quad (2)$$

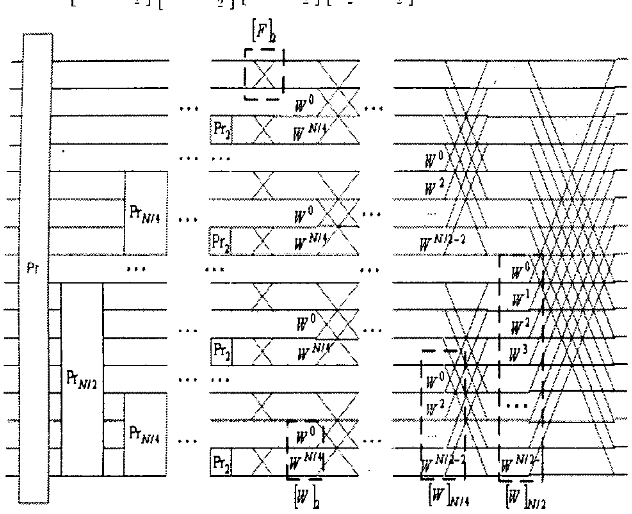

Fig.2 Butterfly data flow diagram of the proposed computation of the N-by-N DFT matrix

4. Element-WISE Inverse Sparse Matrix Decomposition for HWT matrix

The general recursive form for HWT (wavelet transform based on the Haar matrix) matrix can be represented by

$$[A]_N = r([P_i]_N)^{-1} \begin{bmatrix} I_{\frac{N}{2}} & 0 \\ 0 & P_{\frac{N}{2}}^{-1} \end{bmatrix} \begin{bmatrix} I_{\frac{N}{2}} & 0 \\ 0 & A_{\frac{N}{2}} \end{bmatrix} \begin{bmatrix} I_{\frac{N}{2}} & 0 \\ 0 & Pj_{\frac{N}{2}}^{-1} \end{bmatrix} \begin{bmatrix} I_{\frac{N}{2}} & I_{\frac{N}{2}} \\ I_{\frac{N}{2}} & -I_{\frac{N}{2}} \end{bmatrix} ([P_j]_N)^{-1} \quad (3)$$

The butterfly data flow diagram is shown as in Fig.3.

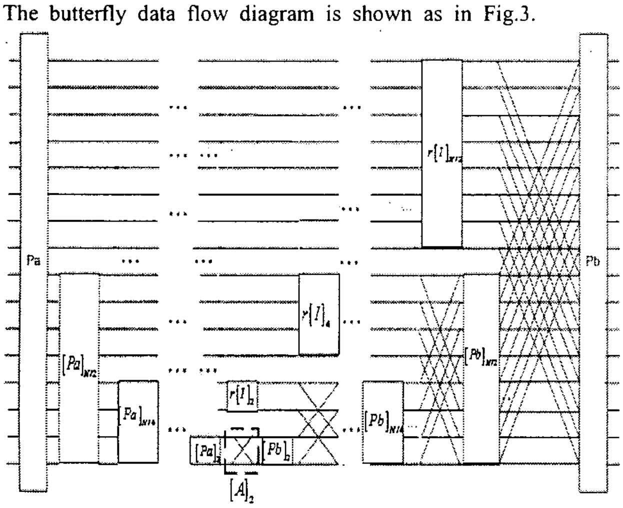

Fig.3 Butterfly data flow diagram of the proposed computation of the N-by-N HWT matrix

5. Conclusion

In this paper, we derive the recursive formulas for DCT-II and HWT matrices. The results show that the DCT-II, DFT [5] and HWT matrices can be unified by using the same sparse matrix decomposition algorithm based on Jacket matrix, and recursive architecture within some characters changed.

Asillustrated in Fig.1, Fig.2, Fig.3, we find that the DFT computation can be from the computation of the DCT matrix by replacing the sub-matrix $[D]_N$ to $[W]_N$, and the permutation matrix $[K]_N$ to $[\Pr]_N$.Also the HWT computation can be from the computation of the DCT matrix not only to replace sub-matrix $[D]_N$ by $[\Pr]_N$, and the permutation matrix $[K]_N$ by $[\Pr]_N$, but also to multiply some special matrices at the output of HWT. As a result, a simple generalized block diagram for DCT/DFT/HWT hybrid architecture and its fast algorithm can be shown as in Fig.4. In this figure, we joint DCT, DFT and HWTcomputations into one chip or one kind of processing architecture, where we use one switching box to control the output data flow. This result is useful to develop the united chip for video coding and digital modulations.

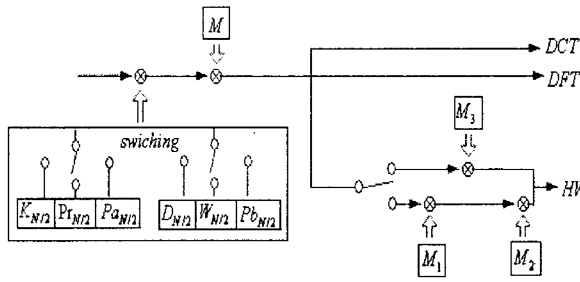

Fig.4. A simple DCT/DFT/HWT hybrid architecture.

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