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Hadamard - Center Line Symmetric Haar에 의한 Image Data 처리에 관한 연구

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Image Data Processing by Hadamard -Center Line Symmetric Haar

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* Abstract

A hybrid version of the Hadamard and Center Line Symmetric Haar Transform(H-CLSH) called H-CLSH is defined and developed.

Efficient algorithms for fast computation of the H-CLSH and its inverse are developed. The H-CLSH is applied to digital signal and image processing and its utility and effectiveness are compared with Hadamard-Haar discrete transforms on the basis of some standard performance criteria.

1. Introduction

Digital signal and image processing has come into prominence in recent years.

This requires, in many cases, utilization of discrete orthogonal transform, Fourier, Haar, discrete linear basis, and discrete cosine have already been utilized in these areas.

This utilization is stimulated in part by the rapid development of digital hardware efficient algorithms for fast implementation of the orthogonal transforms have further accelerated the effectiveness, leading to the design and development of special purpose digital processors tailored for specific transforms.

Since the linear transformation of image data results in compactness of its energy into fewer coefficients, image processing by transform techniques can lead to lower transmission rates with negligible image degradation.

M.Narasimahan had shown Hadamard-Haar Transform.

However, this paper will be shown Hadamard - Center Line Symmetric Haar Transform.

2. CLSH matrices

The Haar matrix consists of plus and minus ones and zero elements.

The CLSH is the linear symmetric matrix in vertical center axis of Haar matrix examples of 4 x 4 and 8 x8 Haar and CLSH matrices are shown below.

(1식) $$[H_a]_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ \sqrt{2} & -\sqrt{2} & 0 & 0 \\ 0 & 0 & \sqrt{2} & -\sqrt{2} \end{bmatrix}$$

(2식) $$[CLSH]_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ -1 & -1 & 1 & 1 \\ 0 & 0 & -\sqrt{2} & \sqrt{2} \\ -\sqrt{2} & \sqrt{2} & 0 & 0 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 1 & 0 & 0 \\ -1 & 1 & 0 & 0 \\ 0 & 0 & \sqrt{2} & 0 \\ 0 & 0 & 0 & \sqrt{2} \end{bmatrix} \begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & -1 & 1 \\ -1 & 1 & 0 & 0 \end{bmatrix}$$

(3식) $$[CLSH]_8 = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & -\sqrt{2} & -\sqrt{2} & \sqrt{2} & \sqrt{2} \\ -\sqrt{2} & -\sqrt{2} & \sqrt{2} & \sqrt{2} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & -\sqrt{2} & 0 \\ 0 & 0 & 0 & 0 & -\sqrt{2} & \sqrt{2} & 0 & 0 \\ 0 & 0 & -\sqrt{2} & \sqrt{2} & 0 & 0 & 0 & 0 \\ -\sqrt{2} & \sqrt{2} & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

By the following algorithm, the K-th order CLSH matrix can be produced.

Theorem 1.

(4식) $H_a(1) = \begin{bmatrix} 1 & 1 \\ -1 & 1 \end{bmatrix}$

(5식) $I_{2^K} = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$

Theorem 2.

(6식) $CLSH(K+1) = \begin{bmatrix} H(K) \otimes (1,\ 1) \\ 2^{K/2} I_{2^K} \otimes (-1,\ 1) \end{bmatrix}$

where, $\otimes$ denotes the Kronecker product operator and K is positive integer.

3.Comparison of Haar and CLSH

(A) Haar Transform

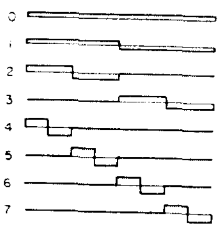


Fig.1.Haar transform basis functions for N=8.

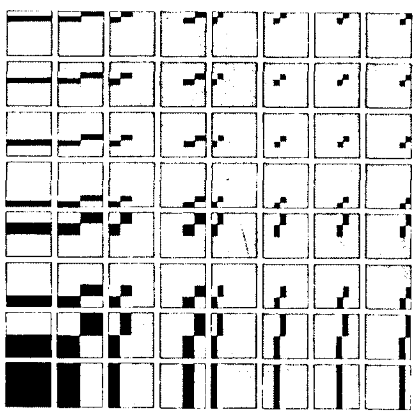


Fig.2.Haar transform basis planes for N=8. Black=1,white=2,slash=3, and x=don't care.

(B) CLSH Transform

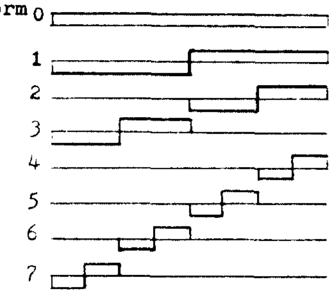


Fig.3.CLSH Transform basis functions for N=8.

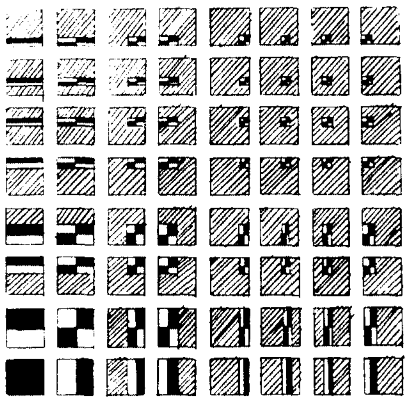


Fig.4.CLSH Transform basis planes for N=8,

The characteristic of CLSH has some property Haar, that is, periodic, completed orthogonal. The H-CLSH transform has a direction of localization of Center signal.

We propose a new CLSH transform that is better than Haar of center signal.

Table 1.CLSH Truth table for basis planes.

Slash	White	Black	CLSH
0	0	0	0
0	2	0	1
0	0	1	1
0	2	1	2
3	x	x	3

4. H-CLSH Transform

The H-CLSH is a new hybrid transform which is satisfied the property of Hadamard and CLSH.

(7식) $\left[H\text{-}CLSH_r(n)\right] = \left[H(r)\right] \otimes \left[CLSH(n-r)\right]$

where $n=2^N$ and rth order is H-CLSH Transform matrix of size $(2^r \times 2^r)$.

Some examples are shown below.

$$\left[H\text{-}CLSH_1(3)\right] = \left[H(1)\right] \otimes \left[CLSH(2)\right]$$

$$= \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \otimes \begin{bmatrix} 1 & 1 & 1 & 1 \\ -1 & -1 & 1 & 1 \\ 0 & 0 & -\sqrt{2} & \sqrt{2} \\ -\sqrt{2} & \sqrt{2} & 0 & 0 \end{bmatrix}$$

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

(8식)

$$= \begin{bmatrix} 10001000 \\ 01000100 \\ 00100010 \\ 00010001 \\ 1000\text{-}1000 \\ 01000\text{-}100 \\ 001000\text{-}10 \\ 0001000\text{-}1 \end{bmatrix} \begin{bmatrix} 11000000 \\ \text{-}11000000 \\ 00\sqrt{2}00000 \\ 000\sqrt{2}0000 \\ 00001100 \\ 0000\text{-}1100 \\ 000000\sqrt{2}0 \\ 0000000\sqrt{2} \end{bmatrix} \begin{bmatrix} 11000000 \\ 00110000 \\ 00\text{-}110000 \\ \text{-}11000000 \\ 00001100 \\ 00000011 \\ 000000\text{-}11 \\ 0000\text{-}1100 \end{bmatrix}$$

(9식) $\left[H\text{-}CLSH_2(4)\right] = \left[H(2)\right] \otimes \left[CLSH(2)\right]$

$$= \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix} \otimes \begin{bmatrix} 1 & 1 & 1 & 1 \\ -1 & -1 & 1 & 1 \\ 0 & 0 & -\sqrt{2} & \sqrt{2} \\ -\sqrt{2} & \sqrt{2} & 0 & 0 \end{bmatrix}$$

Fig.6 shows the signal flow graph of Equation(8). In computer simulation, it is expanded to 64 x 64 matrix.

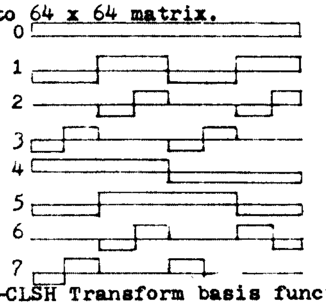
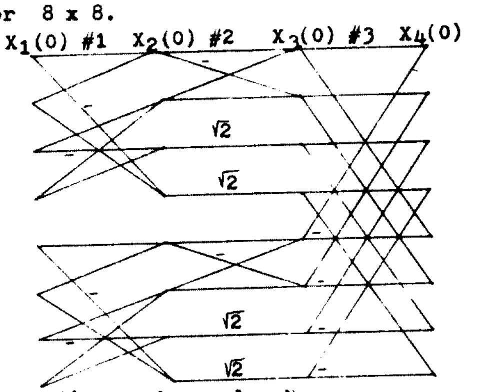


Fig.5. H-CLSH Transform basis function for 8 x 8.



Iteration number = $\log_2 N$

Fig.6. Flow graph for computation of H-CLSH.

We find out sparse matrices factorial Eq(8) and designed signal flow graph Fig.(6).

Table 2. Compare to computing velocity of H-CLSH and Fast H-CLSH.

Form	H-CLSH		Fast H-CLSH		Improvement Ratio	
N*N	Add	Mult	Add	Mult	Add	Mult
8*8	56	16	20	4	2.8	4
16*16	240	32	56	8	4.3	4
EQ.	N(N-1)	2*N	N(n-1)+N/2	N/2		

The fast H-CLSH can be used to increase the computing speed as indicated in the signal flow graph (Fig.6) and Table(2).

In multiplication fast H-CLSH is faster than H-CLSH by 4 times and in addition about n times.

5. **Computer** Simulation

We simulate the 32 gray levels Lincoln **image** with 64 x 64 pixels to Hadamard and H-CLSH in same condition, and the flow graph is Fig.7.

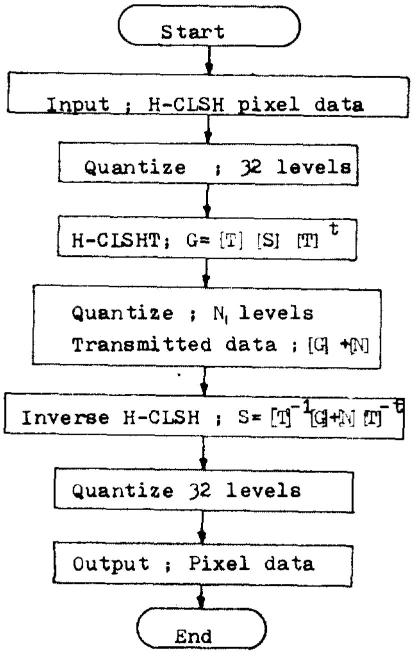


Fig.7. Computer simulation flow graph.

6. Conclusions

The H-CLSH, the hybrid version of the Hadamard and the CLSH, is defined and developed. The H-CLSH is superior to Haar or CLSH in terms of data compression, computational complexity and variance distribution.
The Sparse matrix factoring of these later transforms is utilized in developing the efficients algorithms for fast implementation of H-CLSH.

The H-CLSH is orthogonal as Haar-Hadamard transform.

The H-CLSH has property of concentrated in localized regions which is better than Haar-Hadamard of computer simulation.

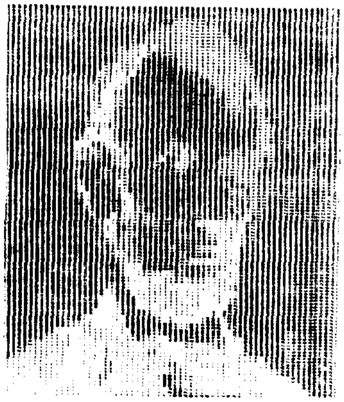
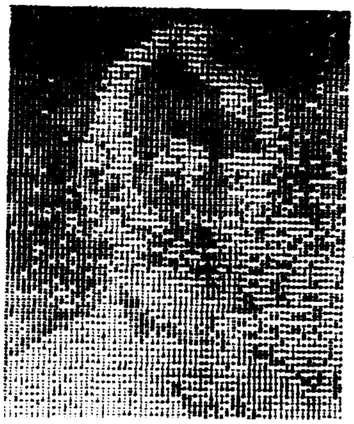
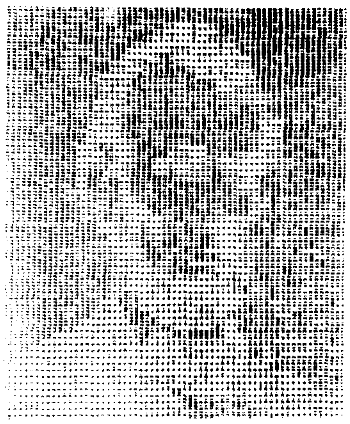


Fig.8. 32 gray levels original Lincoln image.



(a) Hadmard-Haar



(b) Hadmard-CLSH

Fig.9. 64 quantize levels H-Haar and H-CLSH image.

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