IMAGE CODING USING FSVQ WITH DYNAMIC STATES ACCORDING TO THE EDGES IN THE DCT DOMAIN

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ABSTRACT

In this paper, we propose a finite state vector quantization(FSVQ) with dynamic states according to the edges for image coding. A state is dynamically selected by considering the edge orientation of 4 neighboring blocks of a coding block. The state is decided as a part of the state blocks according to the edge characteristic. A state codebook is generated by reordering the super codebook using weighted nearest neighbor rule. This algorithm, different from CVQ, is devised to preserve edges at low bit rates without sending overhead bits for class information. In comparison with side match vector quantization(SMVQ) which is an example of FSVQ in the spatial domain, memory requiring for the storage of state codebook is further reduced because state space is reduced. Simulation result shows 31.62dB in PSNR (Peak Signal to Noise Ratio) at the 0.432 bit/pixel with fixed length code.

1. INTRODUCTION

Vector Quantization(VQ) is an efficient method for image compression. As the dimension of VQ increases, its compression efficiency is raised. However, VQ's dimension is limited due to computational complexity. An ordinary VQ can not effectively reduce interblock correlation. To solve this problem, VQs with memory, for example, predictive VQ[1], finite State VQ[2,3], and address VQ[4] have been proposed.

Classified VQ(CVQ) has each codebook according to the edge characteristic, therefore edge blocks are coded as visually good quality. Ramamurthi et al.[5] have initially proposed CVQ in the spatial domain, and then CVQ in the DCT domain has been proposed by Kim et al.[6]. Its main issues are the scheme of classifier and the number of class and the size of each codebook.

The searching ranges of FSVQ are the subset of the super codebook which is called a state codebook. Its advantage is the reduction of computational complexity and memory. The main point is next-state functions for generating the state codebook. A FSVQ for image coding has been developed as SMVQ and OMVQ in the spatial domain by Kim[2]. Adaptive FSVQ for moving picture coding has been proposed by Chen et al.[3]. Compared with spatially fixed state in these methods, the state is dynamically determined by considering the orientation of edges in our algorithm. The proposed algorithm in this paper utilizes the advantage of CVQ and FSVQ.

The organization of this paper is as follows. Section 2 describes the proposed algorithm. Section 3 presents the simulation results and compares with DCT+CVQ[6] and SMVQ[2]. Section 4 conculdes this paper.

2. PROPOSED FSVQ WITH DYNAMIC STATES

A FSVQ can be defined as a mapping from $R^k \times S$ to a subset of a super codebook, where R^k is the vector space and S is the state space. To decide the state of current input vector, a next state function is used according to the neighboring blocks previously coded.

$$S_n = f(\hat{X}_{NW}, \hat{X}_N, \hat{X}_{NE}, \hat{X}_W) \qquad (1)$$

Blocks are classified as 5 categories by edge classifier. Classified categories are shade, horizontal, vertical, diagonal and complex edge. In the process, four neighboring blocks (N,NE,NW,W) are considered as Fig. 1. They are candidate blocks for selecting the state blocks. One or two of four adjacent blocks are selected as the state blocks. After the state blocks are selected, the state consists of a partial coefficients of the state blocks according to the edge orientation. The state codebook is constructed with a small codewords from the super codebook by the order of smallest frequency matching distortion(FMD) with the selected AC coefficients *in the DCT domain* between the state and the super codebook. The size of the state codebook is much smaller than that of the super codebook.

DC and AC coefficients in the DCT domain are seperately coded. DC coefficient is scalar quantized

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uniformly. AC coefficients are coded using the state codebook by minimum MSE rule.

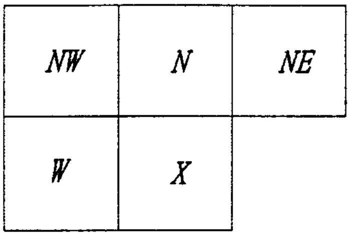


Fig. 1 Indexing of 4 neighboring blocks.

2.1 The Edge Classifier

Edge characteristic in the DCT domain is reflected in AC coefficients[6]. A (MxN) block is classified into 5 categories by means of DCT coefficients as follows.

$$\text{AC} = \sum_{i=0}^{M-1}\sum_{j=0}^{N-1} AC_{ij}^2 - AC_{00}^2 \quad (2) \qquad V = \sum_{j=1}^{N-1} AC_{0j}^2 \quad (3)$$

$$H = \sum_{i=1}^{M-1} AC_{i0}^2 \quad (4) \qquad D = \sqrt{V+H} \quad (5)$$

where, $AC_{00} = DC$, and vector size is MxN.

if $D < th_0$	shade block
else if $V/AC > th_1$	vertical edge block
else if $H/AC > th_1$	horizontal edge block
else if $\lvert(H-V)/AC\rvert < th_2$	diagonal edge block
else	complex edge block

We select the thresholds (th0, th1 and th2) heuristically by computer simulation. Diagonal edge block, whose vertical energy is similar with horizontal one, can be classified easily. Block size is selected as 4x4.

2.2 State Assignment

The state blocks are selected by classified results of 4 neighboring blocks as follows.

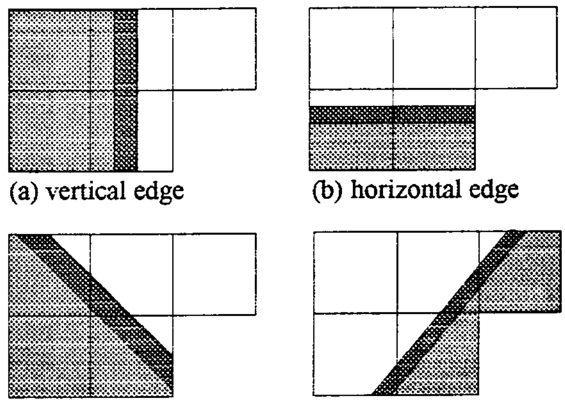
(1) In case that 4 neighboring blocks are all the shade blocks. *N block* is used as the state block.

(2) In case that N block is vertical block, or W block is horizontal, or NE/NW block is diagonal block.

We assume that edges may have a continuity (Fig.2). Therefore, The state block is determined to make the edge continuity between current *X block* and adjacent blocks. For example, if *N block* is classified as vertical one, *N block* is selected as the state block by vertical edge continuity. And if *N block* is classified as vertical and *W block* as horizontal, we can't decide whether current *X block* has a continuity with *N block* or *W block*, therefore these 2 blocks are decided as the state blocks, and then, state codebooks are independently constructed by each state block.

(3) In cases that is different from above cases.

In this case, the number of the state blocks is two. One is *N block*. The other is the block with largest MSE(mean square error) between *N block* and *W,NW,NE blocks*. The reason that *N block* is always selected as the state block is its higher correlation with current *X block* in comparison with the others.



(a) vertical edge (b) horizontal edge

(c) diagonal edge

Fig.2 Continuity of edges.

2.3 Reordering Method

We choose a partial AC coefficients in the state block as the state. When the state block is shade, the state consists of AC_{01}, AC_{10}, and AC_{11} (Fig.3(a)). When state block is vertical and horizontal, the state contains (AC_{01}, AC_{02}, AC_{03}) and (AC_{10}, AC_{20}, AC_{30}), respectively. The state of diagonal and complex edge block are the shaded coefficients in Fig. 3(d) and (e). Frequency matching distortion (FMD) used for the generation of the state cobook of shade block is calculated as (6). However, FMD for another edge blocks is obtained as (7), which is thought of a mean absolute error normalized by AC energy. Super codebook is reodered into a state codebook by the order of the smallest FMD.

This method provides that the continuity of edges is preserved because the state codebook is constructed in preference to the edge continuity. Another advantage is the reduction of computational complexity in comparison with nearest neighbor design[3].

$$FMD_S(S,X) = \sum_{i,j \in S} (S_{i,j} - X_{i,j})^2 \qquad (6)$$

$$FMD_E(S,X) = \sum_{i,j \in S} \left| \frac{S_{i,j} - X_{i,j}}{AC} \right| \qquad (7)$$

where, $S_{i,j}$ is the state and $X_{i,j}$ is the coefficients of the super codebook.

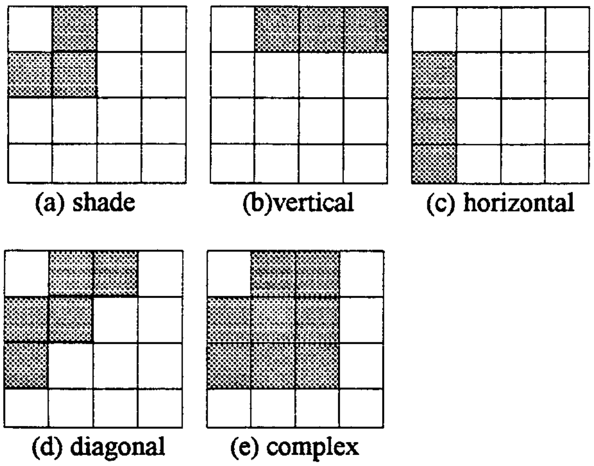


Fig. 3 Selected AC coefficients which consist of state.

2.4 Encoding Process

DC and AC coefficients are separately coded. DC coefficient is predicted as the DC coefficient of the state block selected. When prediction error is over the threshold(Thd), it is uniformly quantized and Huffman coded. AC coefficients are coded using the state codebook generated by the above algorithm. When the coded MSE is over the threshold (Ths), it is coded by the full search of the super codebook to avoid large error.

Overhead bits whether DC transmission and/or switching to the super codebook or not are coded with variable length. Block diagram of the proposed algorithm is shown in Fig.4.

3. SIMULATION RESULTS

Codebooks are designed with only AC coefficients by LBG algorithm[7]. Five (512x512)images are used for codebook design. Lena image for test is not included in training images. The thresholds used in the edge classifier are th0=30, th1=0.8 and th2=0.3. PSNR is defined as (8) used for the criterion of performance.

$$PSNR = 10\log_{10} \frac{255^2}{(\frac{1}{m})^2 \sum_{i=1}^{m} \sum_{j=1}^{m} (x_{i,j} - \hat{x}_{i,j})^2} \qquad (8)$$

where $x_{i,j}$ and $\hat{x}_{i,j}$ is original and reconstructed gray level, respectively.

The performance of proposed algorithm at different size in both super and state codebook is shown in Fig.5. Encoding thresholds are selected as Thd=30 and Ths=200. SMVQ and DCT+CVQ are compared with proposed algorithm. SMVQ shows the saturation of performance according to the rise of the bit rates. DCT +CVQ has a poor performance in the lower bit rates. PSNR of the proposed algorithm increases about 0.5-2.0dB at the same bits/pel compared with existing algorithms. Fig. 7 is the reconstructed image by the modified SMVQ with switching between the super codebook and state codebook. Fig. 8 is the reconstructed image by the proposed algorithm. Proposed algorithm gives 31.62dB at a fixed bit rate of 0.432 bpp.

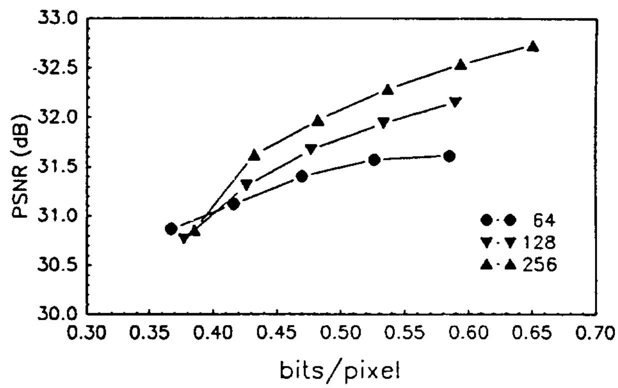


Fig.5 Simulation results are shown with variable size of super codebook(64,128,256). The size of state codebook is varying with 4,8,16,32,64.

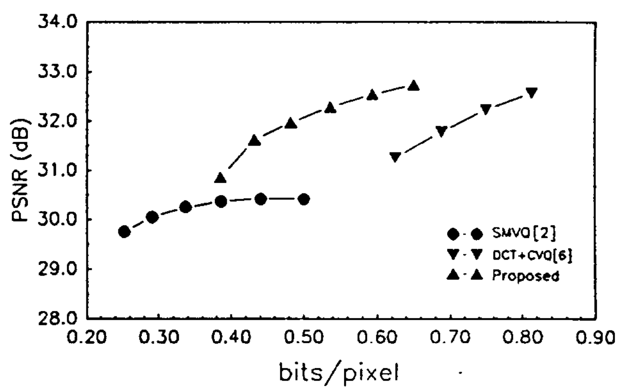


Fig.6. Comparison of performance is shown. Super codebook size is 256. The size of state codebook is varying with 4,8,16,32,64,128. DCT+CVQ results are cited from[6].

4. CONCLUSIONS

We propose a new finite state vector quantizer with dynamic states according to the orientation of edges. It provides to select the state codebook to preserve edge efficiently. State codebook is generated by reorderimg the super codebook using the smallest FMD. The advantages are the coding efficiency without overhead bits and the reduced storage memory for the state codebook compared with the existing FSVQ.

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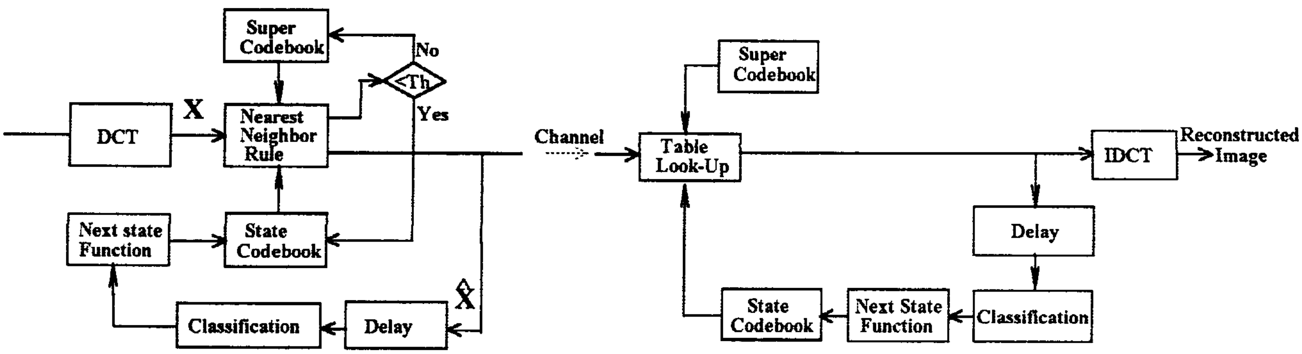

Fig. 4 Block diagram of the proposed algorithm.

Fig. 7 Reconstructed image by SMVQ (0.440 bpp, 30.42 dB).

Fig. 8 Reconstructed image by proposed algorithm (0.432 bpp, 31.62 dB).