

ADCTVQ: A New Method for Image Coding and Compressing

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ABSTRACT

This paper presents a new method for image coding and compressing -- ADCTVQ (Adaptive Discrete Cosine Transform Vector Quantization). In this method, DCT conforms to visual properties and has an encoding ability which is second only to the best transform KLT, and vector quantization can maintain the minimum quantization distortions and greatly increase compression ratio. In order to improve the compression result, an adaptive strategy of selecting reserved region patterns is applied to preserve the high energy at the same compression ratio. Experiments show that the results are still satisfactory at the compression ratio greater than 20.

Keywords: Image compression, Image coding, Vector quantization.

I. Introduction

The technology of image coding and compressing has recently been used in communication, medical engineering and bioengineering etc, more and more intensively. The study of this field has made much progress, but, because of advances of science and technology, particularly the advances of satellite remote sensing, it is required for the higher compressing ratio, the better results and the less running time.

The main present methods for image coding and compressing are outlined as follows:

- i. Predictive technology. It uses the largely redundant property of image data in space domain to encode and transmit the predictive error. The study of vision physiology shows that the human eyes pay more attention to the area where the visual intensity changes sharply in visual field[1]. The quantization errors of the predictive technology is greater in high frequency region and smaller in low frequency region, therefore the results of predictive technology is contrary to that of vision physiology.
- ii. Transform technology. It uses the technology of frequency domain processing. Because the transform technology mainly considers the properties of the frequency domain, it meets the requirements of visual

properties.

iii. Vector quantization. The basic idea of vector quantization is to maintain the minimum quantization distortions, so the method doesn't meet the requirements of visual properties.

iv. Compound coding. It results from combining several different methods. The generally used combining schema is predictive method + transform method [2].

The above methods of coding and compressing have some shortcomings in meeting the above requirements [3], so we proposed a new method for image coding and compressing -- ADCTVQ (Adaptive Discrete Cosine Transform Vector Quantization). This method combines the transform technology which meets the requirements of visual properties, and the vector quantization technology which maintains the minimum quantization distortions, to construct a compound image coding and compressing system. As we know, KLT is the best among the transform methods, but it has no fast algorithm, so it can not be applied to practical use. The study has shown that DCT has a base vector closing to KLT and its ability to encode and compress is second only to KLT among all the orthogonal transforms[4][5]. In addition, considering DCT has fast algorithms, we select DCT as the transform method of the system. In order to improve the compression result, an adaptive strategy of selecting reserved region patterns is applied to preserve the high energy at the same compression ratio. Experiments show that the results are still satisfactory at the compression ratio greater than 20.

II. Design of ADCTVQ system

A. DCT transform and its fast algorithm

The two-dimension DCT is represented as follow.

$$F(u, v) = \alpha_0 \sum_{i=1}^N \sum_{j=1}^N f(i, j) \cos \frac{(2i+1)u\pi}{2N} \cos \frac{(2j+1)v\pi}{2N}$$

$$u, v = 0, 1, 2, \dots, N-1$$

$$f(i, j) = \alpha_1 \sum_{u=1}^N \sum_{v=1}^N c(u, v) F(u, v) \cos \frac{(2i+1)u\pi}{2N} \cos \frac{(2j+1)v\pi}{2N}$$

$$i, j = 0, 1, 2, \dots, N-1$$

$$\text{Where, } \alpha_0, \alpha_1 = \frac{4}{N^2}$$

$$c(m_1, m_2) = \begin{cases} \frac{1}{2}, & m_1 = m_2 = 0 \\ \sqrt{\frac{1}{2}}, & m_1 m_2 = 0 \text{ AND } m_1 \neq m_2 \\ 1, & m_1 m_2 > 0 \end{cases}$$

$$c(m_1, m_2) = c(m_1) c(m_2)$$

W.H.Chen's matrix decomposition algorithm is used as the fast DCT algorithm of the system [6].

B. Image partition

In order to make our system integral, structural and parallel, an original image should be parted into a number of blocks and the size of the blocks processed every time by DCT must be optimized, because the smaller the size, the more boundary effects, while the greater the size, the more storage spaces and the longer running time. By doing experiments in our system, we select the size of block to be 16*16 for a 256*256 image, and then the image is parted into 256 blocks. The blocks are respectively transformed, quantized and inverse-transformed, etc.

C. Selecting reserved region patterns

When the DCT process ends, we get a series of coefficient submatrixes related to the above image blocks. In general, DCT coefficients have properties as follows:

- i. The correlation between transform coefficients is little.
- ii. The energy of the coefficient matrix is mainly in low frequency region.

According to the properties above, the compression process is to eliminate the high frequency coefficients and reserve the low frequency coefficients. Supposing there are some reserved regions in which coefficients contain most of the high energy, then the seven kinds of reserved region patterns *a, b, c, d, e, f* and *g* are most possible (Fig. 2-1). The shadow parts in Fig. 2-1 are reserved regions.

Upon the seven kinds of reserved region patterns, statistics experiments about the energy distribution of coefficient matrix have been made with three typical images which were *girl*(256*256,8), *lady*(256*256,8), *X-Raychest*(256*256,8). In order to do a series of experiments, we set up a relation between the experiment number and the numbers of coefficients in reserved region. Suppose the experiment number is *i*, then we set the numbers of coefficients in reserved region to be $i*(i+1)/2$. Doing experiment, we compute the energy in reserved region according to the seven kinds of reserved region patterns for every block, select the pattern which has the highest energy among the seven kinds of patterns to be the optimum pattern of the block, and then count up the occurrence times of every pattern as the optimum pattern. The statistics results are respectively represented in Tab. 2-1(*girl*), Tab. 2-1(*lady*), Tab. 2-3(*X-Raychest*). Please notice that the values corresponding to a pattern in the tables is the occurrence times of the pattern as the optimum pattern.

It can be seen from the tables that the seven kinds of patterns do not occur with the same probability, the pattern *a, d, e, f* and *g* are most likely to happen. When more than one pattern are used in the system, a number of bits are required for every block to tell which pattern has been used. In order to reduce the bits, we restrict the numbers of patterns to be four, then we generate pattern *h* by integrating pattern *f* and *g* according to the geometrical properties of them (Fig. 2-1), so we select pattern *a, d, e* and *h* as the four kinds of reserved region patterns in ADCTVQ system. During the data transmission, it is required to add only a two-bit identifier for every coefficient submatrix.

D. Adaptive strategy

In order to observe the difference between non-adaptive and adaptive compression, a comparison experiment is carried out. For the non-adaptive compression, we simplify circle symmetric covariance model as pattern *a*, set all the coefficients outside the reserved region as zero, perform DCT inverse transform and compute signal/noise ratio SNR. For the adaptive compression, under the condition that the size of reserved regions is the same as the non-adaptive compression, we introduce the adaptive strategy, i. e. select the kind of pattern whose energy is the highest among the four kinds of patterns to be reserved region, set the part outside the reserved region as zero and perform DCT inverse transform and compute signal/noise ratio SNR. The comparison of SNR for the non-adaptive and adaptive compression with *girl, lady* and *X-Raychest* images are represented in Fig. 2-2.

The experiment shows that the result of adaptive compression is much better than that of non-adaptive

compression. Therefore we apply the adaptive strategy in our system.

E. Vector generation

We set the size of reserved region to be the half of the size of submatrix, then the vector generation of the four kinds of patterns are as follows:

Taking the pattern d as standard pattern in which each line of reserved region is a vector (Fig. 2-3), and the other kinds of patterns are transformed into the form of pattern d by moving the coefficients in area $p1$ to area $p2$. All the lines in reserved regions, except the first line, are 16-dimension vectors. The first line is 15-dimension vector, for the up-left corner coefficient of the submatrix is a scalar.

F. Codebook organization and quantization process

We use a probability method and LBG method to generate and train several codebooks in which each codeword is a 16-dimension vector [7]. The codebooks respectively contain 1024 codewords, 512 codewords, etc. Organizing a codebook, we sort the codebook with $|c|$ in monotonically decreasing order if c is a codeword in the codebook, making the searching range less than 128 codewords.

The quantization process of a vector in a coefficient submatrix is to substitute the vector with a codeword in the codebook if the Euclid distance between the codeword and the vector is minimum. Because what is transmitted in data channel is not the vector itself, but the identifier of a corresponding codeword in the codebook, i. e. if there are 1024 codewords, 10-bit is wide enough to represent any codeword, therefore the compression ratio is greatly increased.

G. Structure of ADCTVQ system

The brief structure of ADCTVQ system is shown in Fig. 2-4.

III. Experiment results and conclusion

We have implemented ADCTVQ System on MICROVAX-II Computer based on GIPSP image processing software. We used the system to compress *girl*, *lady* and *X-Raychest* images, which are black-white and come from the standard image base SIDBA. Fig. 3-1, Fig. 3-2 and Fig. 3-3 respectively represent the original images and results. For every image, the three different compression ratios are reached by applying codebooks with different codewords. It can be seen that the resulting images are basically the same as the original images when the compression ratio c_r is greater than or equal to 20.

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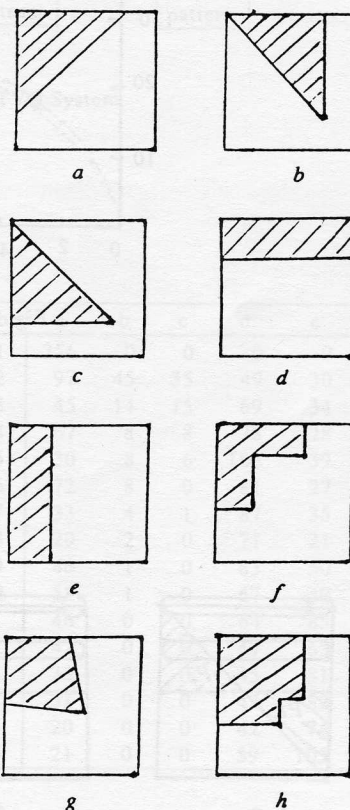


Fig. 2-1 Reserved Region Patterns

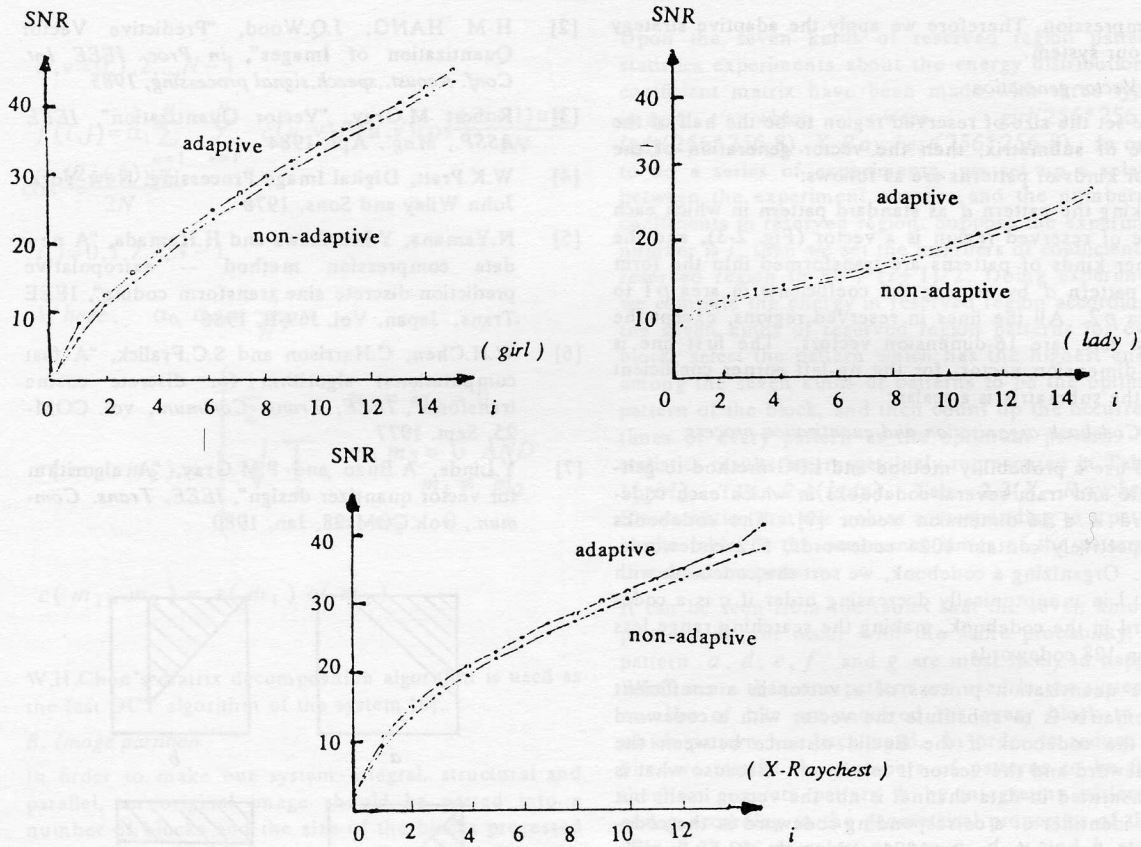


Fig. 2-2 SNR Comparison

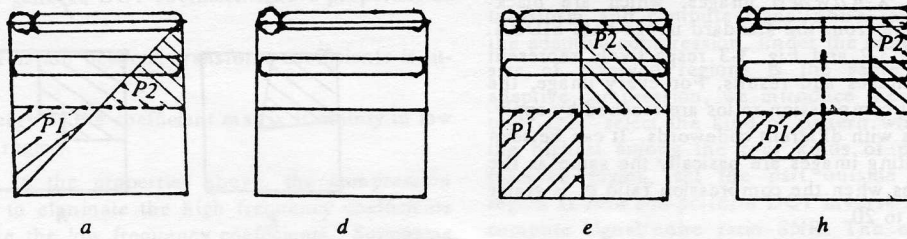


Fig. 2-3 Vector Generation

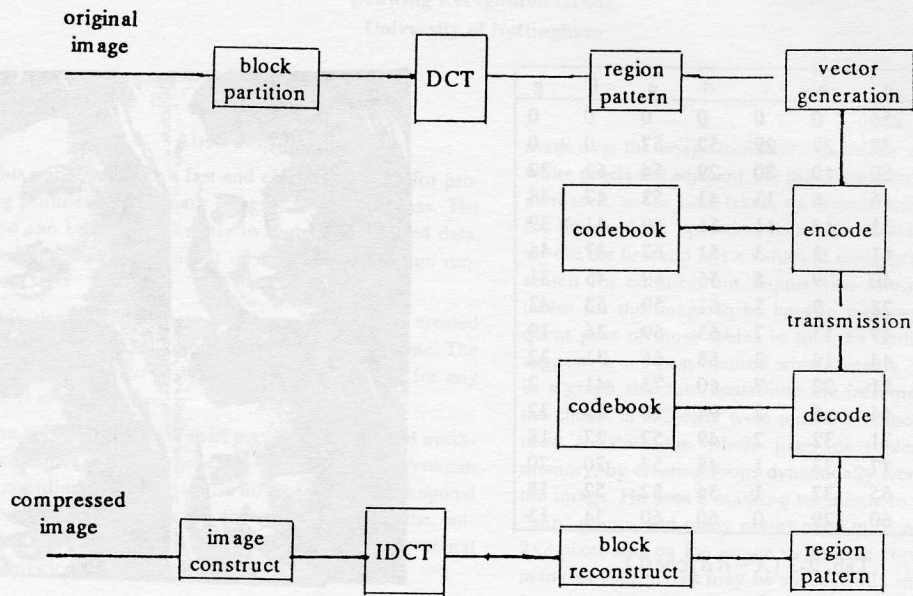


Fig. 2-4 The Brief Structure of ADCTVQ System

No	a	b	c	d	e	f	g
1	256	0	0	0	0	0	0
2	75	29	31	71	50	0	0
3	53	11	14	34	43	70	31
4	78	4	9	47	38	40	40
5	61	5	4	52	52	37	45
6	87	4	3	52	48	33	29
7	74	3	2	65	52	37	23
8	50	6	1	54	36	63	46
9	62	2	1	57	55	60	19
10	69	3	0	45	57	44	38
11	69	1	0	68	61	54	3
12	73	2	0	44	43	46	48
13	75	1	0	36	46	48	50
14	77	1	0	28	47	53	50
15	36	0	0	35	45	86	54
16	59	0	0	61	64	47	25

Tab. 2-1 (girl)

No	a	b	c	d	e	f	g
1	256	0	0	0	0	0	0
2	97	45	35	49	30	0	0
3	45	14	15	69	34	44	35
4	67	8	8	78	28	10	57
5	30	8	6	103	39	27	43
6	72	8	0	81	27	26	42
7	33	4	1	87	35	40	56
8	29	2	0	71	21	36	97
9	46	1	0	83	50	31	45
10	55	1	0	67	49	26	58
11	46	0	0	64	85	51	10
12	42	0	0	47	65	57	45
13	33	0	0	45	81	64	33
14	31	0	0	43	82	48	52
15	20	0	0	42	74	63	57
16	21	0	0	59	105	33	38

Tab. 2-2 (lady)

No	a	b	c	d	e	f	g
1	256	0	0	0	0	0	0
2	89	29	29	52	57	0	0
3	50	10	20	29	54	61	32
4	46	6	13	43	53	47	48
5	31	14	11	51	69	41	39
6	41	3	3	51	67	47	44
7	40	9	6	56	69	45	31
8	28	9	3	61	59	53	43
9	49	13	7	63	69	36	19
10	44	12	3	68	66	31	32
11	51	22	7	60	73	41	2
12	44	6	2	94	18	30	32
13	71	32	2	49	57	27	18
14	77	33	1	48	57	20	20
15	65	32	1	36	52	52	18
16	60	29	0	60	60	34	13

Tab. 2-3 (X-Raychest)



Fig. 3-2 (lady)

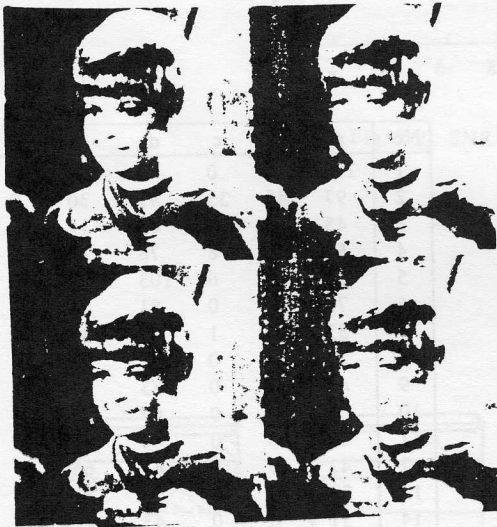


Fig. 3-1 (girl)

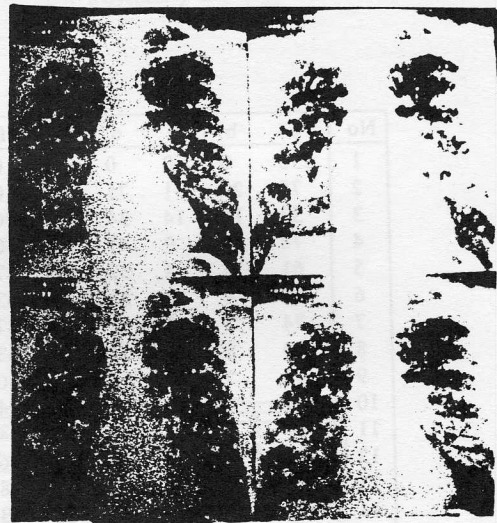


Fig. 3-3 (X-Raychest)

I	II
III	IV

- I. original image
- II. compression ratio is 21
- III. compression ratio is 23
- IV. compression ratio is 26