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Progressive Views of JPEG Compressed Data Based on Probability Distribution of Nonzero Coefficients

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ABSTRACT

A progressive viewing scheme is described for sequential JPEG compressed data. The scheme represents the compressed data by a linked list of minimum coded units and determines the probability distribution of nonzero AC coefficients from the list. By dividing the distribution into uniform sub-intervals, the scheme determines the coefficient bands each of which is used in reconstructing the image for its progressive stage. Progressive view experiments on JPEG compressed data have been carried out, for performance comparison, on the three probability distributions including two additional weighted ones. Better progressive viewing images are usually obtained when the probability distribution weighted by quantized coefficients is used.

Ⅰ. Introduction

JPEG DCT-based compression processes[1] are widely used in various still image compression applications. Among the processes, the baseline, which is a sequential process, is the most popular one because the JPEG standard requires any JPEG decoder implementation to include the baseline decoder. The progressive JPEG process can be used in coding of images. But the progressively compressed data are not guaranteed to be decoded.

Many new techiques[2][3][4][5] have been proposed for progressive encoding of still images since the progressive JPEG was introduced. They require to use their own unique scheme for progressive view of compressed data. Although progressive viewing techniques [6], [7] called image browsers are available, they are not applicable directly to JPEG compressed data.

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A progressive viewing technique, which is applicable to sequential JPEG compressed data, is suggested in this paper. The technique, first, computes the probability distribution of nonzero DCT coefficients from image blocks. The probability distribution, which can be weighted, is used in determining the coefficient bands for a given number of progressive viewing stages. Finally, the incremental image at each stage is constructed using the coefficients in the band for the stage and added to the image reconstructed at the previous stage.

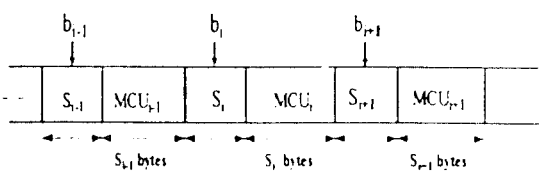
The paper is organized as follows. In the next section, a linked list buffer is addressed for JPEG compressed data and three methods computing the probability distribution of nonzero coefficients are described in detail. And the method determining the coefficient bands is, also, described. In the third section the progressive viewing procedure is provided. In the fourth section is carried out progressive viewing performance of the suggested scheme based on the experimental results.

Ⅱ. Determining DCT Coefficient Bands

It is convenient to handle JPEG compressed data put in a linked list of minimum coded data units (MCUs). It is because the size of JPEG compressed data for each MCU is variable and, for progressive views, faster and/or easier multiple accesses to each individual MCU is required. From the linked list, DCT coefficients of each individual block can be easily extracted.

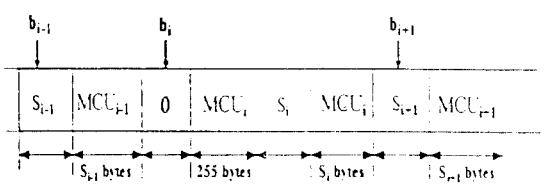
2.1 Linked List of JPEG Compressed Data

Image blocks in a busy part of an image area will have more compressed data than those in a less busy part will do. And the blocks in a MCU represent a contiguous part of the image area with different color primaries involved.



$$b_i = b_{i-1} + S_{i-1} + 1$$

a. When MCU_i has less than or equal to 255bytes of compressed data



$$b_{i+1} = b_i + S_i + 256$$

b. When MCU_i has more than 255bytes of compressed data

S_i : one byte length descriptor

b_i : pointer to S_i for MCU_i

Fig. 1 The linked list showing the positions b_{i-1} of MCU_{i-1} MCU_i and MCU_{i+1}

An MCU, which can be identified by entropy decoder, should be padded with 1-bits to complete the final byte and stuffed with a zero byte if needed. Such MCUs are put in the linked list with length descriptors as shown in Fig. 1. When an MCU has less than or equal to 255 bytes, the MCU has one length descriptor as shown in Fig. 1a. If the MCU has more than 255bytes, the MCU must have one nonzero length descriptor and one or multiple zero byte length descriptors.

The linked list delimits consecutive MCUs by inserting the relative start positon of the subsequent MCU at the begining of the oecured MCU. When the MCUi has less than or equal to 255bytes of compressed data, the start position b_i+1 of the subsequent MCU_i+1 is obtained by $b_i = b_{i-1} + S_{i-1} + 1$. If the MCU_i has more than 255bytes, S_i is set to 0 and the start position bi+1 of the subsequent MCU_i+1 is obtained by $b_{i+1} = b_i + S_i + 256$.

2.2 Determining DCT Coefficient Bands

DCT coefficients in the zigzag sequence are grouped into disjoint bands for a progressive view. Determination of the bands is important for quality of progressive viewing images because the coefficients in a band are the ones used for quality improvement of progressive images. Better progressive viewing images can be obtained if uniform incremental image quality can be achieved at each progressive stage. Making uniform the nonzero coefficient probability distribution of the bands is required for better progressive image reconstruction. Let L be the given number of progressive viewing stages and let each viewing stage take all the DCT coefficients from the band assigned for the stage. Then the L band start indices to the coefficients in the zigzag sequence can be determined by the following three methods.

-Method A-

· Use probabilities of being nonzero for AC coefficients

Let $\{B_{ij}(k),\ k=1,\ 2,\cdots,63\}$ be the entropy decoded data (quantized DCT coefficient in the zigzag sequence) of jth block in a MCU and let M and N be the total number of blocks in a MCU and the total number of MCUs in the compressed data, respectively. Let $\{C_{ij}\{k\}\ k=1,\ 2,\cdots,63\}$ be constructed such that

$C_{ij}(k)=1$ if $B_{ij}(k)\neq 0$,
$C_{ij}(k)=0$ otherwise

Then, the total number T_{nz} of the nonzero coefficients in the compressed data can be obtained from

$$T_{nz}=\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}\sum_{k=0}^{63}C_{ij}(k) \tag{1}$$

The nonzero coefficient counts $\{q_j=j,\cdots,63\}$, their probabilities $\{p_j,\ j=1,\cdots,63\}$, and their accumulated probabilities $\{a_j,\ j=1,\cdots,63\}$ are obtained from

$$q_j=\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}C_{ij}(k),\ k=1,\cdots,63$$

$$p_j=\frac{q_j}{T_{nz}} \tag{2}$$

$$a_j=\sum_{k=1}^{i}p_k$$

The band start indices $I_1, I_2,\cdots, I_{L-1}$ are determined such that they satisfy

$$\frac{a_{I_i-1}+a_{I_i}}{2}\leq\frac{i}{L}<\frac{a_{I_i}+a_{I_i-1}}{2} \tag{3}$$

where $i=1,\ 2,\cdots,L-1$
and a_0 is assumed to be 0.
The index I_L is fixed to have the value of 63.

−Method B:
· Use probabilities, of being nonzero, weighted by quantized coefficient values.

Probabilities of being nonzero for AC coefficients are weighted by their AC coefficient values and used for determining the L indices to the zigzag sequence Specifically, the band start indices can be obtained by the same procedure in the method A where $C_{ij}(k)$ is replaced by

$$C_{ij}(k)=\left|B_j(k)\right| \text{ for } i=0,\ 1,\cdots,N-1,\ \text{and } j=0,\ 1,\cdots,M-1,\ \text{and } k=1,\ 2,\cdots,63 \tag{4}$$

−Method C:
· Use probabilities of being nonzero, weighted by dequantized coefficient values.

Probabilities of being nonzero are weighted by their dequantized AC coefficient values. Specifically, the band indices can be obtained by the same procedure as in the method A where $C_{ij}(k)$ is replaced

$$C_{ij}(k)=\left|B_{ij}(k)\right|\times q^*(k) \text{ for } i=0,\ 1,\cdots,N-1,\ \text{and } j=0,\ 1,\cdots,M-1,\ \text{and } k=1,\ 2,\cdots,63 \tag{5}$$

Different image components can have different $q^*(j)$ values.

Ⅲ. Procedure for Progressive View

Four functional units are shown in Fig 2.

The first initialization unit reads a DCT based sequential JPEG compressed data file and puts them in a linked list. The size of compressed data in the linked list increases slightly because relative size information for each MCU Fig. 2 Flow of the Progressive viewing schemeis added to the compressed data. The first unit also clear a buffer for the reconstructed image.

In the second unit, the band start indices are determined by one of three methods described in section 2.2. This unit requires to scan compressed data of all MCUs to compute the the probability distribution of nonzero AC coefficients. Entropy decoding for each

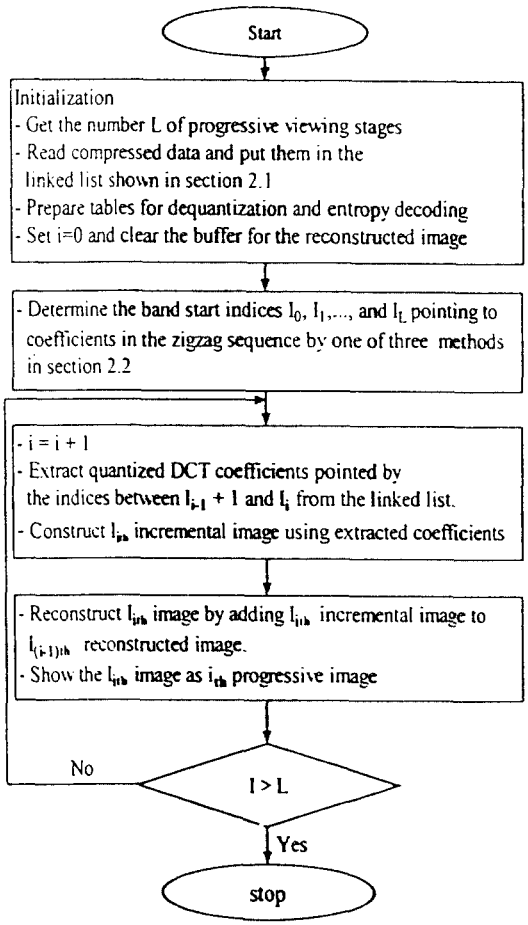


Fig. 2 Flow of the progressive viewing scheme

MCU must be carried out for the test of being nonzero of the coefficients. Luminance block only in a MCU can be used for determining the band start indices. Or both luminance and chrominance blocks can be used.

The third unit takes coefficients only in the i_{th} band for all the blocks all MCUs and constructs i_{th} incremental image by appling the dequantization and inverse DCT to those coefficients. Tables, for dequantizer and/or entropy decoder, loaded already from the compressed data file can be used in this unit. The last unit shows the ith reconstructed image obtained by adding the incremental image to the $(i-1)_{th}$ reconstructed image.

Ⅳ. Experimental Results

JPEG standard test images called zelda, barbara, boats, and blackboard are compressed and used for progressive viewing experiments. All the test images have the same spatial resolution of 576 lines × 720 pixels/line and the same colors of Y,Cb,Cr primaries. Babara. jpg, blackboard.jpg, boats.jpg, and zelda.jpg are the compressed data files.

When the test data is represented by the JPEG default color space(4:2:2 YCrCb), it has 1620 MCUs and one MCU has six blocks of 8x8 pixels.

When L is given to be 5, Table 1 shows the band start indices I_1, I_2, I_3, I_4, and I_5, for each compressed image, determined by the three methods described in section 2.2 and lists the SNR values, with respect to the final image, of the images reconstructed at each progressive stage. Table 1, also, shows the incremented compressed data($\triangle$C in percentage) at each progressive stage.

From Table 1, it is found that the start index of each band produced by the method B has generally the lower value than those by the methods A and C have. It is because the values at lower indices from use of the JPEG non-uniform quantizer based on the human visual system. It can be said that most band start indices produced by the method A have lower values than those by the method C have and the indices determined by using all the Y, Cr, and Cb blocks have lower values than those from all the Y blocks only.

The lower values of the band start indices determined by the method B requires for the progressive image reconstruction to use smaller incremental compressed data($\triangle$C) and, thus, to show the progressive reconstructed images of lower quality(smaller SNR values). Because the higher frequency coefficients, which are located at the higher positions in the zigzag sequence, are less sensitive to the human vision system and fast image reconstruction at the initial stages is possible by the smaller amount of lower frequency

Table 1. Band start indices I_i, to coefficients in the zigzag sequence, determined by the methods. A, B, and C described in section 2.2 and progressive image quahities for barbara.jpg, blackboard.jpg, boats.jpg, and zelda.jpg.

Methods	colors used	Viewing stages(i)	1	2	3	4	5
A	Y	I_i	3	7	12	19	64
		(△C)	(25.77)	(25.19)	(14.92)	(15.96)	(18.16)
		SNR	23.31	25.03	26.02	28.26	–
	Y, Cb, Cr	I_i	3	6	11	18	64
		(△C)	(25.77)	(20.85)	(15.52)	(18.41)	(19.45)
		SNR	23.31	24.60	25.67	28.21	–
B	Y	I_i	1	4	6	12	64
		(△C)	(18.77)	(16.94)	(10.91)	(19.26)	(34.12)
		SNR	22.11	23.75	24.60	26.02	–
	Y, Cb, Cr	I_i	1	3	6	12	64
		(△C)	(18.77)	(11.05)	(17.80)	(19.26)	(34.12)
		SNR	22.11	23.31	24.60	26.02	–
C	Y	I_i	2	6	13	24	64
		(△C)	(25.77)	(20.85)	(22.39)	(17.24)	(13.75)
		SNR	22.98	24.60	26.38	28.66	–
	Y, Cb, Cr	I_i	2	5	12	24	64
		(△C)	(25.77)	(16.97)	(23.14)	(20.37)	(13.75)
		SNR	22.98	24.30	26.02	28.66	–

(a) barbara.jpg

Methods	colors used	Viewing stages(i)	1	2	3	4	5
A	Y	I_i	2	5	9	14	64
		(△C)	(32.71)	(19.98)	(17.31)	(14.28)	(15.71)
		SNR	26.06	28.89	31.67	34.60	–
	Y, Cb, Cr	I_i	2	4	8	13	64
		(△C)	(32.71)	(11.80)	(20.04)	(15.64)	(19.45)
		SNR	26.06	27.42	30.53	33.29	–
B	Y	I_i	1	2	5	8	64
		(△C)	(22.85)	(9.86)	(19.99)	(12.21)	(35.09)
		SNR	24.17	26.06	28.89	30.53	–
	Y, Cb, Cr	I_i	1	2	4	8	64
		(△C)	(22.85)	(9.86)	(11.80)	(20.40)	(35.09)
		SNR	24.17	26.06	27.42	30.53	–

C	Y	I_i	1	3	6	13	64
		($\triangle$C)	(22.85)	(15.73)	(18.40)	(23.57)	(19.45)
		SNR	24.17	27.00	29.76	33.29	–
	Y, Cb, Cr	I_i	1	3	6	12	64
		($\triangle$C)	(22.85)	(15.73)	(18.40)	(20.98)	(22.04)
		SNR	24.17	27.00	29.76	32.86	–

(b) blackboard.jpg

Methode colors used		Viewing stages(i)	1	2	3	4	5
A	Y	I_i	3	6	11	16	64
		($\triangle$C)	(35.53)	(17.78)	(16.60)	(12.97)	(17.12)
		SNR	26.79	29.15	31.68	34.67	–
	Y, Cb, Cr	I_i	2	5	9	15	64
		($\triangle$C)	(30.53)	(18.70)	(16.23)	(14.35)	(19.19)
		SNR	26.03	28.55	30.96	34.22	–
B	Y	I_i	1	3	5	9	64
		($\triangle$C)	(20.99)	(14.54)	(13.70)	(16.23)	(34.54)
		SNR	24.19	26.79	28.55	30.96	–
	Y, Cb, Cr	I_i	2	3	5	9	64
		($\triangle$C)	(20.99)	(14.54)	(13.70)	(16.23)	(34.54)
		SNR	24.19	26.79	28.55	30.96	–
C	Y	I_i	2	4	8	15	64
		($\triangle$C)	(35.53)	(6.07)	(19.76)	(19.45)	(19.19)
		SNR	26.03	27.34	30.04	34.22	–
	Y, Cb, Cr	I_i	1	4	7	14	64
		($\triangle$C)	(20.99)	(20.61)	(15.72)	(22.00)	(20.67)
		SNR	24.19	27.34	26.94	34.42	–

(c) boats.jpg

Methods colors used		Viewing stages(i)	1	2	3	4	5
A	Y	I_i	2	4	7	12	64
		($\triangle$C)	(41.70)	(11.31)	(17.56)	(14.45)	(15.51)
		SNR	31.04	32.28	35.15	37.57	–
	Y, Cb, Cr	I_i	1	4	6	11	64
		($\triangle$C)	(30.52)	(21.96)	(13.48)	(14.63)	(19.41)
		SNR	28.81	32.28	34.61	37.11	–

B	Y	I_i	1	2	4	7	64
		(△C)	(30.52)	(10.65)	(11.31)	(17.56)	(29.96)
		SNR	28.81	31.04	32.28	35.15	–
	Y, Cb, Cr	I_i	1	2	4	7	64
		(△C)	(30.52)	(10.65)	(11.31)	(17.56)	(29.96)
		SNR	28.81	31.04	32.28	35.15	–
C	Y	I_i	1	2	5	11	64
		(△C)	(30.52)	(10.65)	(20.31)	(19.11)	(19.41)
		SNR	28.81	31.04	33.74	37.11	–
	Y, Cb, Cr	I_i	1	2	5	10	64
		(△C)	(30.52)	(10.65)	(20.31)	(17.29)	(21.23)
		SNR	28.81	31.04	33.74	36.91	–

(d) zelda.jpg

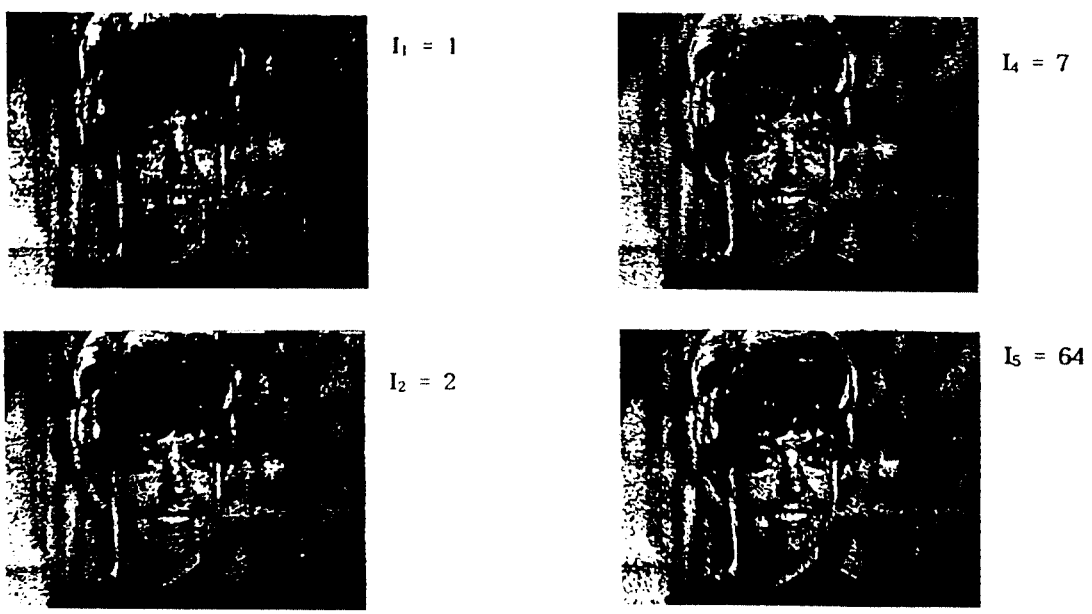


Fig. 3 Five progressive images of zelda.jpg using the band start indices determined by the method B.

coefficients, the coefficient bands determined by the method B is preferable to use in the progressive image reconstruction. Fig. 3 shows one such five progressive viewing images of zelda.jpg.

V. Summary and Conclusions

A progressive viewing scheme for sequential JPEG compressed data has been described. The scheme represents the compressed data by a linked list of MCUs for efficient use of memory buffer and then determines the coefficient bands for a progressive view from the probability distribution of nonzero coefficients. Three probability distributions, non-weighted and two weighted, are used for progressive performance comparison.

Progressive view experiments on four JPEG compressed images have been carried out. The experimental results show that the probability distribution weighted by quantized coefficient values is preferable to use in determining the coefficient bands for better progressive viewing performance.

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