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(54) **METHOD OF REMOVING BLOCKING ARTIFACTS IN A CODING SYSTEM OF A MOVING PICTURE**

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,903,138 A 2/1990 Aragaki
4,941,043 A 7/1990 Jass
(Continued)

FOREIGN PATENT DOCUMENTS

EP 0808068 11/1997
(Continued)

OTHER PUBLICATIONS

Byeungwoo Jeon et al, Blocking Artifacts reduction in image compression with block boundary discontinuity criteron, Circuits and System for Video Technology, IEEE Transactions on, vol.: Jun. 8, 1998, pp. 345-357.

(Continued)

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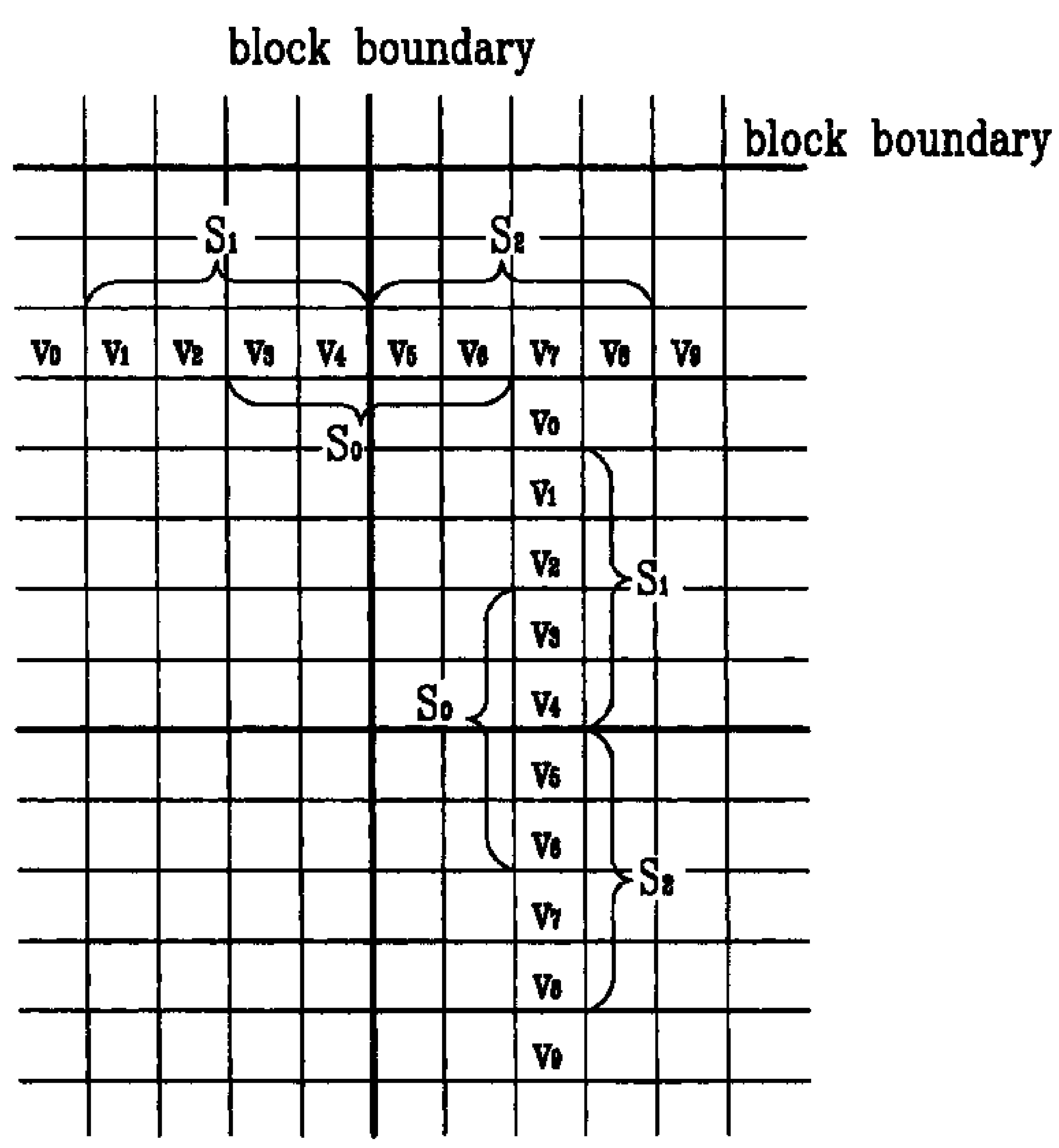
(57) **ABSTRACT**

A method of coding a moving picture reduces blocking artifacts. The method includes defining pixel sets S0, S1, S2 around a block boundary, selectively determining a deblocking mode as a default mode or a DC offset mode depending on the degree of blocking artifacts. If the default mode is selected, frequency information is obtained around the block boundary per pixel using a 4-point DCT kernel, for example, a magnitude of a discontinuous component belonging to the block boundary is replaced with a minimum magnitude of discontinuous components belonging to the surroundings of the block boundary in the frequency domain and the replacing step is applied to the spatial domain. If the DC offset mode is selected and a determination is made to perform DC offset mode, the blocking artifacts in a smooth region are removed in the DC offset mode.

19 Claims, 5 Drawing Sheets



U.S. PATENT DOCUMENTS

5,229,864	A	*	7/1993	Moronaga et al.	382/261
5,337,088	A		8/1994	Honjo	
5,367,385	A	*	11/1994	Yuan	358/465
5,422,964	A		6/1995	Devimeux	
5,454,051	A		9/1995	Smith	
5,565,921	A	*	10/1996	Sasaki et al.	375/240.13
5,590,064	A	*	12/1996	Astle	708/203
5,596,659	A	*	1/1997	Normile et al.	382/253
5,608,652	A	*	3/1997	Astle	708/203
5,629,778	A	*	5/1997	Reuman	382/252
5,677,736	A	*	10/1997	Suzuki et al.	375/240.24
5,680,477	A		10/1997	Asada	
5,740,283	A	*	4/1998	Meeker	382/248
5,787,204	A		7/1998	Fukuda	
5,787,210	A		7/1998	Kim	
5,796,875	A		8/1998	Read	
5,852,682	A		12/1998	Kim	
5,903,679	A	*	5/1999	Park	382/253
5,911,008	A	*	6/1999	Niikura et al.	382/236
5,923,376	A		7/1999	Pullen et al.	
5,937,101	A		8/1999	Jeon	
5,949,917	A		9/1999	Kawasaka	
5,974,196	A		10/1999	Chang et al.	
6,028,867	A		2/2000	Rawson et al.	
6,028,967	A	*	2/2000	Kim et al.	382/268
6,040,879	A	*	3/2000	Park	375/240.27
6,052,490	A		4/2000	Haskell et al.	
6,104,434	A	*	8/2000	Nakagawa et al.	375/240.16
6,144,700	A		11/2000	Kim	
6,151,420	A		11/2000	Wober	
6,167,164	A		12/2000	Lee et al.	
6,188,799	B1		2/2001	Tan et al.	
6,240,135	B1		5/2001	Kim	
6,314,209	B1	*	11/2001	Kweon et al.	382/243
6,317,522	B1		11/2001	Rackett	
6,320,905	B1		11/2001	Konstantinides	
6,463,182	B1		10/2002	Onishi et al.	
6,614,946	B1		9/2003	Edgar	
6,724,944	B1		4/2004	Kalevo	
7,003,170	B1		2/2006	Martucci	
7,003,174	B2		2/2006	Kryukov	
7,006,255	B2		2/2006	Sun et al.	
7,031,393	B2		4/2006	Kondo	
7,054,503	B2		5/2006	Ishikawa	
7,209,594	B1		4/2007	Martucci	
7,233,706	B1		6/2007	Kim	
7,239,755	B1		7/2007	Kim et al.	
7,262,886	B2		8/2007	Kim et al.	
7,277,593	B2		10/2007	Kim	
7,283,681	B2		10/2007	Kim	
7,283,682	B2		10/2007	Kim	
7,289,682	B2		10/2007	Kim	
7,292,733	B2		11/2007	Monobe et al.	
7,305,142	B2		12/2007	Kim	
7,305,143	B2		12/2007	Kim	
7,352,913	B2		4/2008	Karuta et al.	
7,359,569	B2		4/2008	Kim	
7,359,570	B2		4/2008	Kim	
7,362,913	B2		4/2008	Kim et al.	
7,362,914	B2		4/2008	Kim	
7,379,616	B2		5/2008	Kim	
7,379,617	B2		5/2008	Kim	
7,382,930	B2		6/2008	Kim et al.	
7,391,921	B2		6/2008	Kim	
7,391,922	B2		6/2008	Kim	
7,391,923	B2		6/2008	Kim	
7,391,924	B2		6/2008	Kim	
7,394,945	B2		7/2008	Kim	
7,397,853	B2		7/2008	Kwon et al.	
7,397,965	B2		7/2008	Kim	
7,397,966	B2		7/2008	Kim	
7,397,967	B2		7/2008	Kim	
7,400,780	B2		7/2008	Kim	
7,403,667	B2		7/2008	Kim et al.	
7,406,209	B2		7/2008	Kim	
7,437,015	B2		10/2008	Kim	
7,454,082	B2		11/2008	Kim	
7,463,786	B2		12/2008	Kim	
7,492,959	B2		2/2009	Kim	
7,492,960	B2		2/2009	Kim	
7,492,961	B2		2/2009	Kim	
7,496,239	B2		2/2009	Kim	
7,499,598	B2		3/2009	Kim	
2003/0138160	A1		7/2003	Ishikawa	
2003/0194013	A1		10/2003	Alvarez	
2005/0196066	A1		9/2005	Kim et al.	
2005/0243911	A1		11/2005	Kwon	
2005/0243912	A1		11/2005	Kwon	
2005/0243913	A1		11/2005	Kwon	
2005/0243914	A1		11/2005	Kwon	
2005/0243915	A1		11/2005	Kwon	
2005/0243916	A1		11/2005	Kwon	
2005/0244063	A1		11/2005	Kwon	
2006/0159351	A1		7/2006	Bae et al.	
2006/0274959	A1		12/2006	Piastowski	
2007/0071095	A1		3/2007	Lim	
2007/0223835	A1		9/2007	Yamada et al.	
2008/0037893	A1		2/2008	Okumichi et al.	

FOREIGN PATENT DOCUMENTS

JP	2002-232889	8/2002
WO	WO 02/096117	11/2002

OTHER PUBLICATIONS

Barzykina, E et al., Removal of blocking artifacts using random pattern filtering, Image Processing, 1999 International Conference, vol. 3, 1999, pp. 904-908 vol. 2.

Mei-Yin Shen te al., Fast compression artifact reduction technique based on nonlinear filter, Circuits and Systems, 1999. ISCAS '99. Proceedings of the 1999 IEEE International Symposium on, vol. 4, 1999, pp. 179-182.

Yung-Kai Lai et al., Removal of blocking artifacts of DCT transform by classified space-frequency filtering, Signals, System and Computers, 1995, Conference Record of the Twenty-Nine Asilmar Conference on, vol. 2, 1996, pp. 1457-1461.

Kasezawa, T., Blocking artifacts reduction using discrete cosine transfomr, Consumer Electronics, IEEE Transactions on, vol. 43 Issue: 1, Feb. 1997, pp. 48-55.

Avideh Zakhor, "Iterative Procedures for Reduction of Blocking Effects in Transform Image Coding", IEEE Transactions on Circuits and Systems for Video Technology, vol. 2, No. 1, pp. 91-95 (Mar. 1992).

Yongyi Yang et al., "Regularized Reconstructions to Reduce Blocking Artifacts of Block Discrete Cosine Transform Compressed Images", IEEE Transactions on Circuits and Systems for Video Technology, vol. 3, No. 6, pp. 421-432 (Dec. 1993).

Gary J. Sullivan et al., "Motion Compensation for Video Compression Using Control Grid Interpolation", IEEE International Conference, pp. 2713-2716 (1991).

G. de Haan et al., "IC for Motion-Compression 100Hz TV With Natural-Motion Move-Mode", IEEE Transactions on Consumer Electronics, vol. 42, pp. 165-174 (Feb. 1996).

Ozcelik, Taner et al., "Image and Video Compression Algorithms Based on Recovery Techniques Using Mean Field Annealing", Proceedings of the IEEE, vol. 83, No. 2, pp. 304-316, Feb. 1995.

Nakajima, Yasuyuki, et al., "A PEL Adaptive Reduction of Coding Artifacts for MPEG Video Signals", pp. 928-932, IEEE, 1994.

Minami, Shigenobu et al., "An Optimization Approach for Removing Blocking Effects in Transform Coding", *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 5 No. 2 Apr. 1995, 74-82.

Lai, Yung-Kai et al., "Image Enhancement for Low Bit-rate JPEG and MPEG Coding via Postprocessing", *Proc. SPIE* vol. 2727 Feb. 1996, 1484-1494.

* cited by examiner

FIG. 1
Prior art

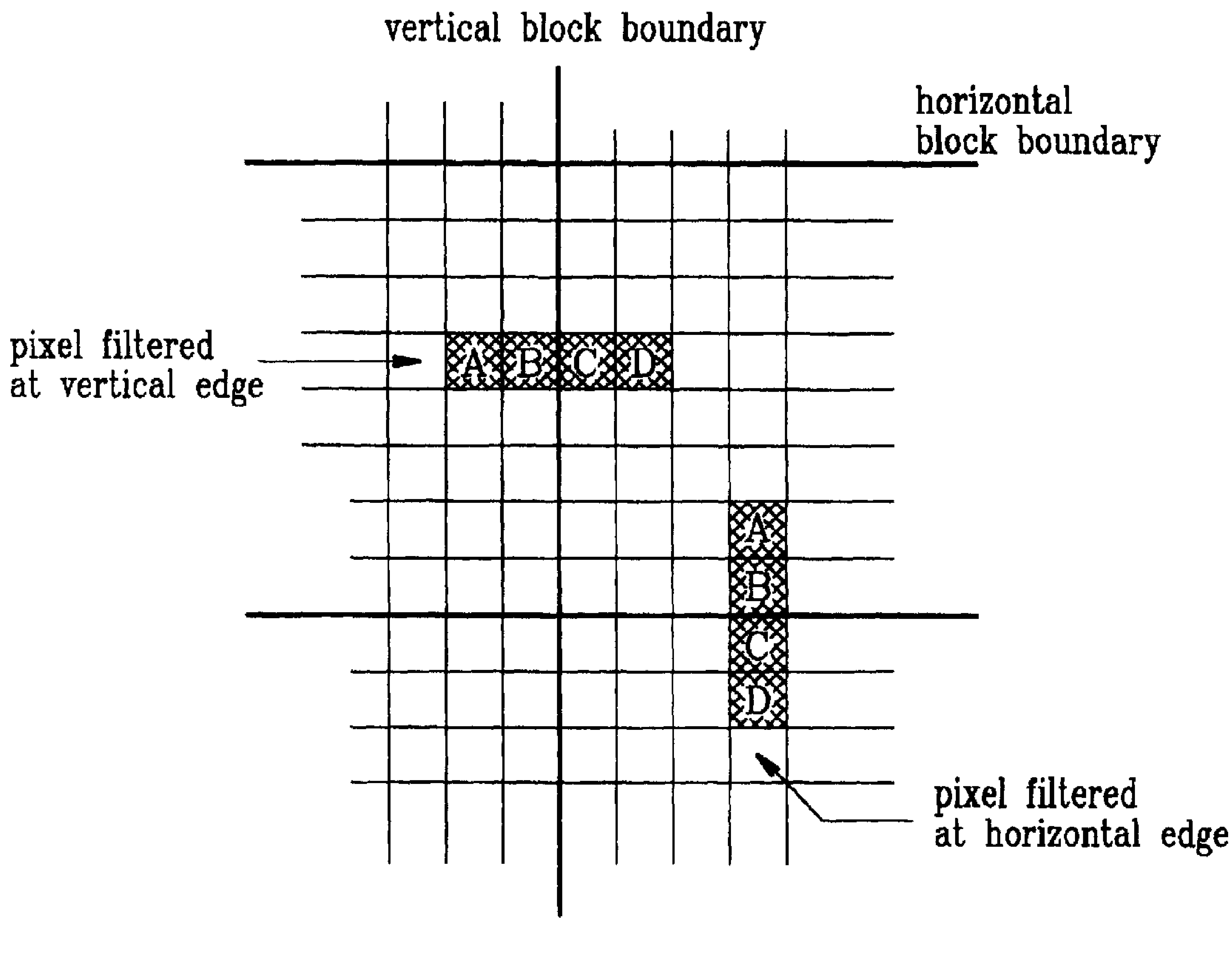


FIG.2

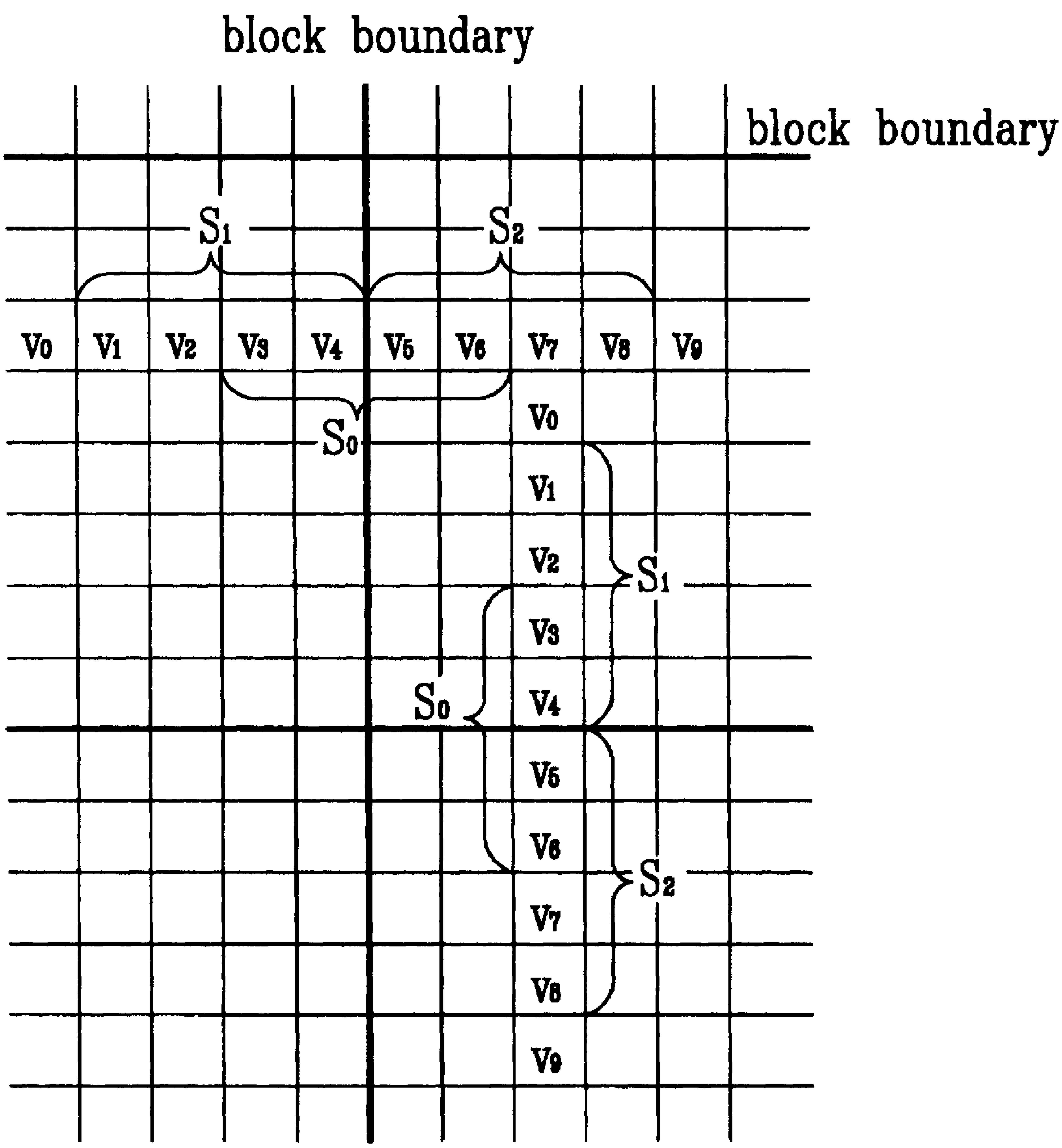

block boundary
block boundary
S1
S2
V0
V1
V2
V3
V4
V5
V6
V7
V8
V9
S0
V0
V1
V2
S1
V3
S0
V4
V5
V6
S2
V7
V8
V9

FIG.3

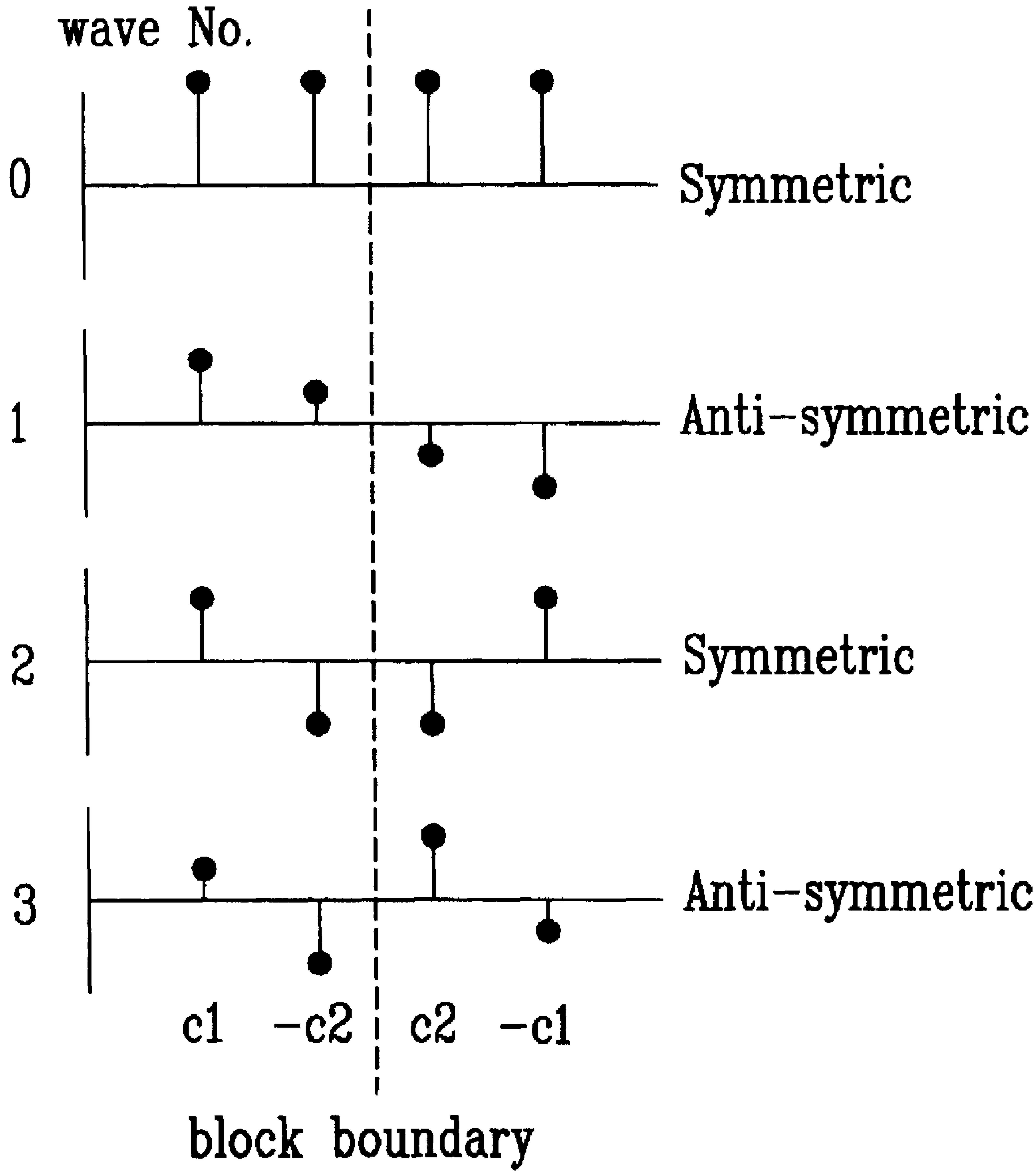
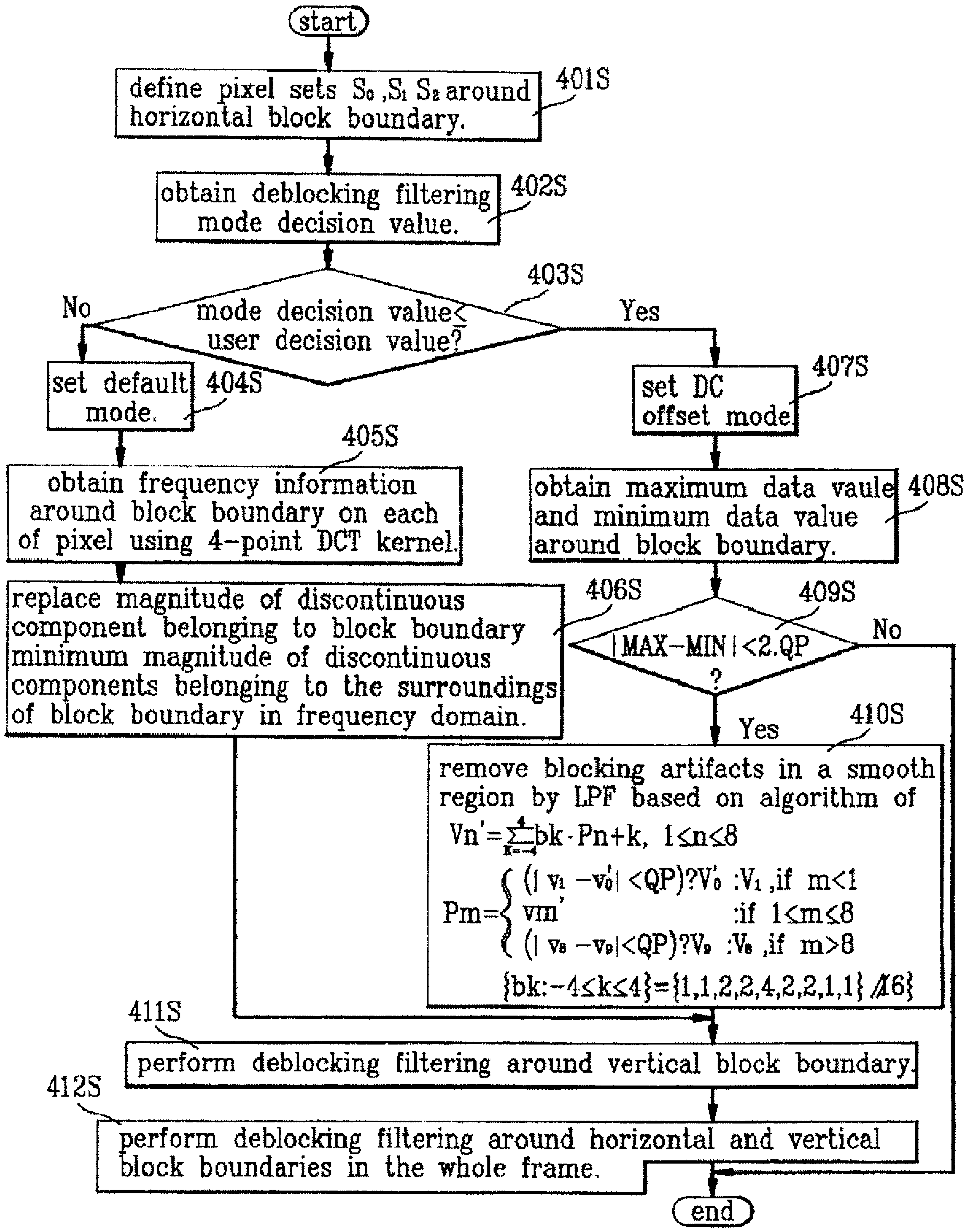

wave No.
0
Symmetric
1
Anti-symmetric
2
Symmetric
3
Anti-symmetric
c1
-c2
c2
-c1
block boundary

FIG.4

- Amended -



$$Vn' = \sum_{k=-4}^{4} bk \cdot Pn+k, \quad 1 \le n \le 8$$

$$Pm = \begin{cases} (|v_1 - v_0'| < QP) ? V_0' : V_1, & \text{if } m < 1 \\ vm' & \text{if } 1 \le m \le 8 \\ (|v_8 - v_9| < QP) ? V_9 : V_8, & \text{if } m > 8 \end{cases}$$

$$\{bk : -4 \le k \le 4\} = \{1,1,2,2,4,2,2,1,1\} / 16$$

FIG.5

post filter simulation results

condition	sequence	QP	bits	PSNR_Y VM Only	Telenor Deblocking	PSL Deblocking	NS Deblocking	SEC Deblocking	SEC Deblocking	LGS Deblocking	LGS+SEC Deblocking
10Kps QCIF 7.5Hz	Hall monitor	17	96583	30.04	30.22	30.14	30.10	30.30	30.20	30.37	30.43
	Container ship	17	93556	29.21	29.29	29.05	29.24	29.38	29.34	29.43	29.50
	Mother & daughter	15	95579	32.32	32.43	32.35	32.30	32.31	32.44	32.49	32.48
24Kbps QCIF 10Hz	Hall monitor	9	236220	33.82	34.03	33.85	33.90	34.09	34.00	34.20	34.24
	Container ship	10	217480	32.36	32.44	32.08	32.36	32.50	32.49	32.54	32.61
	Mother & daughter	8	231791	35.20	35.31	35.19	35.07	35.23	35.25	35.36	35.31
48Kbps QCIF 10Hz	Foreman	13	478108	30.91	30.97	30.89	30.87	30.95	31.00	31.06	31.07
	Coast guard	14	446028	29.01	28.99	28.54	28.97	28.98	28.92	29.09	28.93
	Mother & daughter	7	484656	34.30	34.45	34.28	34.11	34.34	34.36	34.48	34.48
48Kbps CIF 7.5Hz	News	18	472973	31.20	31.32	31.19	31.21	31.33	31.31	31.40	31.40
	Container ship	10	468027	36.06	36.22	36.07	35.93	36.08	36.13	36.18	36.08
	Hall monitor	12	458086	33.59	33.61	33.82	33.64	33.89	33.74	34.02	34.02
112Kbps CIF 15Hz	News	11	1139868	34.00	34.13	34.06	33.97	34.17	34.13	34.26	34.29
	Foreman	30	1184538	28.25	28.33	28.09	28.24	28.23	28.32	28.35	28.37
	Coast guard	29	1172406	26.36	26.35	25.95	26.34	26.31	26.28	26.42	26.28
1Mbps SIF,30Hz	Stefan	13	9796735	29.00	29.02	28.31	28.97	29.05	29.05	29.12	29.13
	Mobile & Calendar	14	10259224	26.25	26.21	25.61	25.68	26.30	26.30	26.29	26.33

METHOD OF REMOVING BLOCKING ARTIFACTS IN A CODING SYSTEM OF A MOVING PICTURE

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

Notice: More than one reissue application has been filed for the reissue of U.S. Pat. No. 6,240,135. The reissue applications are application Ser. Nos. 11/834,312; 11/834,347; 11/851,551 (the present application); application Ser. Nos. 11/851,529; and 11/851,517, all of which are divisional reissues of U.S. Pat. No. 6,240,135.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method of coding data, and more particularly, to a method of removing blocking artifacts when coding image signals such as in a moving picture at low-bit-rate.

2. Background of the Related Art

Generally, to efficiently compress a time variable video sequence, it is necessary to remove redundancy in the temporal domain as well as in the two-dimensional spatial domain. In moving picture experts group (MPEG), discrete cosine transform (DCT) is used to remove the redundancy in the two-dimensional spatial domain while a motion compensation method is used to remove the redundancy in the temporal domain.

The DCT is a method of removing the correlativity between data through a two-dimensional spatial transformation. Each block in a picture is spatially transformed using the DCT after the picture is divided into blocks. Data that has been spatially transformed tends to be driven to a certain direction. Only a group of the data driven in the certain direction is quantized and transmitted.

Pictures, which are consecutive in the temporal domain, tend to form motions of a human being or an object at the center of the frame. This property is used to reduce the redundancy of the temporal domain in the motion compensation method. A volume of data to be transmitted can be minimized by taking out a similar region from the preceding picture to fill a corresponding region, which has not been changed (or has very little change), in the present picture. The operation of finding the most similar blocks between pictures is called a motion estimation. The displacement representing a degree of motion is called a motion vector. MPEG uses a motion compensation-DCT method so that the two methods combine.

When a compression technique is combined with a DCT algorithm, the DCT transform is usually performed after input data is sampled in a unit size of 8×8, and the transform coefficients are quantized with respect to a visual property using quantization values from a quantization table. Then, the data is compressed through a run length coding (RLC). The data processed with the DCT is converted from a spatial domain to a frequency domain and compressed through the quantization with respect to the visual property of human beings, not to be visually recognized. For example, since eyes of human beings are insensitive to a high frequency, a high frequency coefficient is quantized in a large step size.

For the quantized data, the data having a relatively high frequency is coded with a short code word. The quantized

data having a low frequency is coded with a long code word. Thus, the data is finally compressed.

In processing a moving picture as discussed above, blocks are individually processed to maximize the compression ratio and coding efficiency. However, the individual process causes blocking artifacts that disturb the eyes of human beings at boundaries between blocks.

A related art method of removing blocking artifacts will be described with reference to FIGS. **1** and **2**. FIG. **1** is a pixel matrix illustrating a method for removing blocking artifacts. FIG. **2** is a pixel matrix illustrating block boundaries in horizontal and vertical directions.

Various algorithms have been presented for removing blocking artifacts that appear in a coding system, which individually processes blocks. For example, MPEG-4 used a deblocking filter by Telenor, which uses the following algorithm:

If B is replaced with B1 and C is replaced with C1,

$B1=B+d1$,

$C1=C-d1$, and

$d1=\mathrm{sign}(d)*(\mathrm{MAX}(0,|d|-\mathrm{MAX}(0,2*|d|-QP)))$

where $d=(3A-8B+8C-3D)/16$ and QP denotes the quantization parameter of the macroblock where pixel C belongs.

In processing a MPEG-4 moving picture, blocking artifacts are removed using the above algorithm to improve picture quality. However, it is difficult to effectively remove the blocking artifacts with the above with a small operation capacity in a real time operation. For example, coding and decoding a moving picture is a real time operation. In other words, to completely remove the blocking artifacts, a large calculation amount is needed, which is undesirable in efficiency.

Alternatively, to remove the blocking artifacts, there is provided a method of changing processes of coding and decoding. This method increases the amount of bits to be transmitted.

Still another method for removing blocking artifacts is based on the theory of projection onto convex sets (POCS). However, this method is applied only to a still picture because of an iteration structure and long convergence time.

Thus, the related art methods for removing blocking artifacts in a coding system of a moving picture have several problems. First, in performing an algorithm for removing the blocking artifacts, a calculation is complicated and the calculation amount and time become correspondingly large. Further, the blocking artifacts are not removed in either complex regions or smooth regions in a picture. In addition, the amount of bits to be transmitted increases.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a method of removing blocking artifacts in a coding system that substantially obviates one or more of the problems due to limitations and disadvantages of the related art.

Another object of the present invention is to remove blocking artifacts when necessary in a smooth portion of a moving picture.

Yet another object of the present invention is to provide a method of removing blocking artifacts in a coding system of a moving picture where blocking artifacts of the moving picture are removed at real time using frequency features around a block boundary without increasing the amount of bits.

To achieve at least the above objects in a whole or in parts, a method of removing blocking artifacts in a coding system according to the present invention includes determining at least pixel sets S0, S1, S2 around a block boundary, selecting one of a default mode and a DC offset mode as a deblocking mode based on an amount of blocking artifacts, deblocking filtering pixels adjacent the block boundary if a default mode is selected, deblocking filtering of pixels adjacent the block boundary if a default mode is selected, and removing artifacts in the DC offset mode when the DC offset mode is selected and a DC offset mode condition is satisfied, where the artifacts are removed in the DC offset mode according to the following equation:

$$v_n = \sum_{k=-4}^{4} b_k \cdot p_{n+k},\ 1 \le n \le 8$$

$$P_m = (|v_1 - v_0| < QP)\,?\,v_0 : v_1,$$

If m<1;

v_m, if $1 \leqq m \leqq 8$;

[$(|v_8-v_9|<QP)v_9:v_8$, if m>8;**]** *$(|v_8-v_9|<QP)?v_9: v_8$, if m>8;*

$\{b_k: -4 \leqq k \leqq 4\} = \{1,1,2,2,4,2,2,1,1\}//16$,

wherein v_0-v_9 are boundary pixels, QP is the quanatation parameter of a block adjacent the block boundary, and v_n is an adjusted pixel value.

To further achieve the above advantages and in accordance with the purpose of the present invention, as embodied and broadly described, a method of removing blocking artifacts in a coding system of a moving picture according to the present invention includes the steps of defining pixel sets S0, S1, S2 around block boundary, selectively determining a deblocking mode as a default mode or a DC offset mode depending on the degree of blocking artifacts after obtaining a mode decision value, obtaining frequency information around the block boundary per pixel using 4-point DCT kernel if the default mode is determined, replacing a magnitude of a discontinuous component belonging to the block boundary with a minimum magnitude of discontinuous components belonging to the surroundings of the block boundary in the frequency domain and applying this replacing step to the spatial domain, judging whether or not it is necessary to perform DC offset mode if the DC offset mode is determined, and removing the blocking artifacts in a smooth region when the judgment is to perform the DC offset mode.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described in detail with reference to the following drawings in which like reference numerals refer to like elements wherein:

FIG. **1** is a diagram showing a pixel matrix illustrating a related art method of removing blocking artifacts;

FIG. **2** is a diagram showing a pixel matrix illustrating block boundaries in horizontal and vertical directions;

FIG. **3** is a schematic diagram showing a 4-point DCT basis;

FIG. **4** is a flow chart showing a preferred embodiment of a method of removing blocking artifacts according to the present invention; and

FIG. **5** is a table showing exemplary results of a preferred embodiment of a method of removing blocking artifacts according to the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In a preferred embodiment of the present invention, blocking artifacts at a block boundary are removed in a frequency domain not a spatial domain. Frequency features around the block boundary are preferably obtained using a 4-point DCT kernel, which can be easily calculated. Thus, a complex region at the block boundary can effectively be processed by extending the smoothness of a picture from the frequency domain to the spatial domain.

Using the 4-point DCT kernel has advantages that frequency analysis is possible and deblocking can easily be processed. Therefore, the 4-point DCT Kernel can efficiently remove the blocking artifacts of a real time moving picture.

The blocking artifacts appear at the block boundary between fixed block patterns in the form of a line of discontinuity. Accordingly, removal of the blocking artifacts involves transformation of the discontinuity of the block boundary region to continuity.

FIG. **2** shows a block boundary region in a horizontal or a vertical direction. In one-dimensional images consisting of four points such as S0, S1 and S2 located around the block boundary, S1 and S2 are individually processed with a block-unit compression method. Thus, S1 and S2 are not influenced by the blocking artifacts. However, S0 is located across a block boundary. Thus, S0 is directly influenced by the blocking artifacts.

In the preferred embodiment according to the present invention, frequency information in S1 and S2 is used to reduce the blocking artifacts from S0. When images change smoothly, image features of S0, S1 and S2 are similar to one another. This means that image features of S0, S1 and S2 are also similar to one another in the frequency domain.

Since the frequency features of S0, S1 and S2 are similar, the frequency component of S0 influenced by the blocking artifacts is adjusted considering the frequency components of S1, S2, which can remove the blocking artifacts. Here, DCT, which is widely applied as an image compression technique, is used as a frequency analysis tool.

The blocking artifacts may appear in both horizontal and vertical block boundaries. In the preferred embodiment according to the present invention, after the blocking artifacts at the horizontal block boundary are removed, the blocking artifacts at the vertical block boundary are removed.

Pixel sets S0, S1 and S2, which overlap, can be defined around the horizontal block boundary. S0 is a 4-point pixel set arranged across the block boundary while S1 and S2 are 4-point pixel sets that adjoin the block boundary.

That is to say, the pixel set S0 contains a discontinuity. The discontinuity in S0 is removed in the preferred embodiment using common information (e.g., between S0 and S2), which are not directly influenced by the discontinuity of the block boundary.

The 4-point DCT basis is used to get information around the block boundary and is shown in FIG. **3**. The 4-point DCT basis vectors have symmetric and anti-symmetric properties. In other words, assuming the 4-point DCT coefficients of S0 are defined as $a_{0,0}$(DC), $a_{1,0}$, $a_{2,0}$, $a_{3,0}$, although both $a_{2,0}$ and $a_{3,0}$ are the high frequency components, $a_{2,0}$ is symmetric and $a_{3,0}$ is anti-symmetric around the center.

As shown in FIG. **2**, since the center of S0 is coincident with the block boundary, a factor directly affecting the block discontinuity is not the symmetric component but the anti-symmetric component. Thus, in the preferred embodiment the magnitude of $a_{3,0}$ in the frequency domain is adjusted based on the anti-symmetric component so that the block discontinuity can be adjusted. An appropriate adjustment of $a_{3,0}$ in the frequency domain is directly related to the removal of the block discontinuity in the spatial domain.

Operations for reduction or removal of the block discontinuity will now be described. In the preferred embodiment, the magnitude of $a_{3,0}$ is replaced with the minimum value of the magnitudes of $a_{3,1}$ and $a_{3,2}$. By doing this, a large blocking artifact, which appears when one side of the block boundary to be processed is smooth, can be removed. For a complex region where both S1 and S2 are the objects of motion (i.e., all the values of the magnitudes of $a_{3,0}$, $a_{3,1}$ and $a_{3,2}$ are large), there is little influence on the block boundary.

A method for removing the blocking artifacts in a default mode in the preferred embodiment is as follows:

$v_4' = v_4 - d$;

$v_5' = v_5 + d$; and

$d \approx CLIP(c_2.(a_{3,0}' - a_{3,0})//c_3, 0, (v_4 - v_5)/2) * \delta(|a_{3,0}| < QP)$,

where $a_{3,0}' = SIGN(a_{3,0}) * MIN(|a_{3,0}|, |a_{3,1}|, |a_{3,2}|)$,

$a_{3,0} = ([c_1 - c_2\ c_2 - c_1] * [v_3 v_4 v_5 v_6]^T)//c_3$,

$a_{3,1} = ([c_1 - c_2\ c_2 - c_1] * [v_1 v_2 v_3 v_4]^T)//c_3$, and

$a_{3,2} = ([c_1 - c_2\ c_2 - c_1] * [v_5 v_6 v_7 v_8]^T)//c_3$.

Thus, boundary pixels v_4 and v_5 that adjoin the boundary are replaced with v_4' and v_5', respectively. QP is the quantization parameter of the macroblock where pixel v_5 belongs. Values c_1, c_2, c_3 are kernel constants used in the 4-point DCT. The values of c_1 and c_2 are approximated to an integer, and the value of c_3 is approximated to a multiple of 2. The values of $a_{3,0}$, $a_{3,1}$, $a_{3,2}$ are evaluated from the simple inner product of the DCT kernel and the pixel sets S0, S 1 and S2.

The condition $|a_{3,0}| < QP$ is used to count the influence of the quantization parameter on the blocking artifacts. The condition $|a_{3,0}| < QP$ also prevents over-smoothing when the blocking artifacts are not very serious. The clipping operation on the compensated value is performed to prevent the direction of the gradient at the block boundary from being enlarged or changed in an opposite direction.

This filtering process is performed in both horizontal and vertical block boundaries. In this manner, the blocking artifacts in the whole frame can be removed.

In the default mode, only the boundary pixel values v_4 and v_5 are compensated. Thus, the default mode is not sufficient to remove the blocking artifacts in a very smooth region, such as a setting in a picture. Therefore, in the preferred embodiment the blocking artifacts in the smooth region are removed by a DC offset mode.

A method for removing the blocking artifacts in the DC offset mode in the preferred embodiment is as follows:

$max = MAX(v_1, v_2, v_3, v_4, v_5, v_6, v_7, v_8)$,

$min = MIN(v_1, v_2, v_3, v_4, v_5, v_6, v_7, v_8)$,

$if(|max - min| < 2QP)$, /*low pass filtering*/

$$v_n = \sum_{k=-4}^{4} b_k \cdot p_{n+k},\ 1 \le n \le 8$$

$$P_m = (|v_1 - v_0| < QP)\,?\,v_0 : v_1,$$

if m<1;

v_m, if $1 \leqq m \leqq 8$;

[$(|v_8 - v_9| < QP) v_9 : v_8$, if m>8;**]** $(|v_8 - v_9| < QP)?v_9 : v_8$, *if m>8;*

$\{b_k : -4 \leqq k \leqq 4\} = \{1,1,2,2,4,2,2,1,1\}//16$.

If the absolute value of the maximum data value minus minimum data value in the block boundary pixels is smaller than twice the quantization parameter (i.e., if deblocking is required), the blocking artifacts in the smooth region are removed by the DC offset mode.

The decision to use the default mode or to use the DC offset mode is preferably made based on the following condition:

$$\text{Mode decision value(eq\_cnt)} = \phi(v_0 - v_1) + \phi(v_1 - v_2) + \phi(v_2 - v_3) + \phi(v_3 - v_4) + \phi(v_4 - v_5) + \phi(v_5 - v_1) + \phi(v_7 - v_8) + \phi(v_8 - v_9),$$

where $\phi(\gamma) = 1$ if $|\gamma| \leqq THR1$ (first threshold value) and $\phi(\gamma) = 0$ otherwise.

If the mode decision value eq_cnt $\geqq$ THR2 (i.e., a second threshold value), the DC offset mode is applied. In the remaining cases, default mode is applied.

A method for removing the blocking artifacts to code a moving picture at low-rate-bit according to the preferred

embodiment of the present invention will be described with reference to FIG. **4**. After beginning in FIG. **4**, control continues to step **401**S. In step **401**S, three pixel sets S0, S1, S2 are defined based on the horizontal block boundary. From step **401**S, control continues to step **402**S.

In step **402**S, the mode decision value (e.g., eq_cnt) is determined and control continues to step **403**S. In step **403**S, the mode decision value is compared with a decision value (e.g., a second threshold value THR2 preferably set by a user) to perform deblocking filtering process by selecting the mode depending on the degree of the blocking artifacts in the picture.

If the determination in step **403**S is negative, control continues to step **404**S where the default mode is set. From step **404**S, control continues to step **405**S where frequency information around the block boundary on each of the pixel is determined, for example, using the 4-point DCT kernel. From step **405**S, control continues to step **406**S.

In step **406**S, the magnitude of the discontinuous component belonging to the block boundary is replaced with the minimum magnitude of the discontinuous components belonging to the surroundings of the block boundary in the frequency domain. This adjusting operation is applied to the spatial domain. That is, the magnitude of the discontinuous component belonging to the block boundary is replaced with the minimum magnitude of the discontinuous components belonging to the surroundings of the block boundary in the spatial domain.

In the default mode of the preferred embodiment, the blocking artifacts are removed in step **406**S using the method as described below:

$v_4' = v_4 - d$;

$v_5' = v_5 + d$; and

$d = CLIP(c_2.(a_{3,0}' - a_{3,0})//c_3, 0, (v_4 - v_5)/2) * \delta(|a_3| < QP)$,

where $a_{3,0}' = SIGN(a_{3,0}) * MIN(|a_{3,0}|, |a_{3,1}|, |a_{3,2}|)$,

$a_{3,0} = ([c_1 - c_2\ c_2 - c_1] * [v_3 v_4 v_5 v_6]^T)//c_3$,

$a_{3,1} = ([c_1 - c_2\ c_2 - c_1] * [v_1 v_2 v_3 v_4]^T)//c_3$,

$a_{3,2} = ([c_1 - c_2\ c_2 - c_1] * [v_5 v_6 v_7 v_8]^T)//c_3$. In the default mode, the blocking artifacts are effectively removed in a complex region. However, the default mode does not sufficiently remove blocking artifacts in a smooth region.

If the determination in step **403**S is affirmative, control continues to step **407**S where the DC offset mode is set to remove the blocking artifacts. From step **407**S, control continues to step **408**S where the minimum and maximum data values (min, max) are determined. From step **408**S, control continues to step **409**S where a determination is made to remove the blocking artifacts in the default mode. If the determination in step **409**S is negative, the process ends. If the determination in step **409**S is affirmative, control continues to step **410**S.

In the DC offset mode according to the preferred embodiment, in step **410**S, the blocking artifacts are removed using the following algorithm.

$max = MAX(v_1, v_2, v_3, v_4, v_5, v_6, v_7, v_8)$,

$min = MIN(v_1, v_2, v_3, v_4, v_5, v_6, v_7, v_8)$,

$if(|max - min| < 2.QP)$, /*low pass filtering*/

$$v_n = \sum_{k=-4}^{4} b_k \cdot p_{n+k},\ 1 \le n \le 8$$

$$P_m = (|v_1 - v_0| < QP)\,?\,v_0 : v_1,$$

if m<1;

v_m, if $1 \leqq m \leqq 8$;

[$(|v_8 - v_9| < QP) v'_9 : v_8$, if m>8;**]** $(|v_8 - v_9| < QP)?v_9 : v_8$, *if m>8;*

$\{b_k : -4 \leqq k \leqq 4\} = \{1,1,2,2,4,2,2,1,1\}//16$.

The maximum data value and the minimum data value in the block boundary pixels are obtained in step **408**S. Then, if the absolute value of the maximum data value minus the minimum data value is smaller than 2QP (i.e., if deblocking is required), the blocking artifacts in the smooth region are removed by the DC offset mode in steps **409**S and **410**S.

From step **406**S and **410**S, control continues to step **411**S. If the deblocking filtering process around the horizontal block boundary is completed, the deblocking filtering process around the vertical block boundary is performed in step **411**S. From step **411**S, control continues to step **412**S.

In step **412**S, the deblocking filtering processes around the horizontal and vertical block boundaries repeat over the whole frame. From step **412**S, the process ends.

FIG. **5** is a table illustrating exemplary PSNR properties according to the method of removing the blocking artifacts of the preferred embodiment. The conditions yielding the exemplary results of FIG. **5** are as follows:

300 frames (only the initial frame was coded in intra.);
Fixed QP;
H.263 quantization;
F_code=1;
Enable DC/AC prediction; and
Rectangular shape VOP.

As shown in FIG. **5**, the method for removing the blocking artifacts of the preferred embodiment improves results relative to VM (no filtering) of MPEG-4.

As described above, the method for removing the blocking artifacts according to the preferred embodiments of the present invention has various advantages. The deblocking filtering process is performed using features of the frequency domain so that the blocking artifacts are effectively removed. Further, the blocking artifacts are removed in both the complex and smooth regions. Thus, an excellent image or picture quality is provided. In addition, amount of bits does not increase.

The foregoing embodiments are merely exemplary and are not to be construed as limiting the present invention. The present teaching can be readily applied to other types of apparatuses. The description of the present invention is intended to be illustrative, and not to limit the scope of the claims. Many alternatives, modifications, and variations will be apparent to those skilled in the art.

What is claimed is:

[**1**. A method for removing blocking artifacts in a coding system of a moving picture comprising the steps of:

determining a plurality of pixel sets around a block boundary;

selecting one of a first mode and a second mode as a deblocking mode based on a degree of blocking artifacts;

performing an analysis, if the first mode is selected, comprising,

obtaining frequency information for each of the plurality of pixel sets,

replacing a magnitude of at least one discontinuous component in the frequency domain of a selected pixel set of the plurality of pixel sets belonging to the block boundary with a magnitude of at least one corresponding discontinuous component belonging to a replacement pixel set of the plurality of pixel sets near the block boundary, and

applying the replaced frequency information of the selected pixel set to the spatial domain to remove the blocking artifacts; and

removing the blocking artifacts in the second mode, if the second mode is selected and a second mode condition is satisfied.]

[**2**. The method as claimed in claim **1**, wherein the magnitude of the discontinuous component of the selected pixel set is replaced with a minimum value of a magnitude of discontinuous components of one of a first pixel set and a second pixel set when the selected pixel set is located across the block boundary and the first and second pixel sets are located within a block adjacent the block boundary.]

[**3**. The method of claim **1**, further comprising determining a mode decision value, wherein the second mode is selected if the mode decision value is greater than a first threshold value.]

[**4**. The method as claimed in claim **3**, wherein mode decision value is determined based on the following equation:

$$\text{mode decision value}=\phi(v_0-v_1)+\phi(v_1-v_2)+\phi(v_2-v_3)+\phi(v_3-v_4)+\phi(v_4-v_5)+\phi(v_5-v_1)+\phi(v_7-v_8)+\phi(v_8-v_9),$$

wherein $\phi(\gamma)=1$ when $|\gamma| \leqq$ a second threshold value and $\phi(\gamma)=0$ otherwise, and wherein v_0-v_9 are boundary pixel values.]

[**5**. The method as claimed in claim **1**, wherein the second mode condition is satisfied when an absolute value of a maximum data value minus a minimum data value in block boundary pixels is smaller than 2QP, wherein the maximum data value=MAX(v_1, v_2, v_3, v_4, v_5, v_6, v_7, v_8), the minimum data value=MIN(v_1, v_2, v_3, v_4, v_5, v_6, v_7, v_8), QP is the quantization parameter of a block adjacent the block boundary and v_1-v_8 are pixels.]

[**6**. The method as claimed in claim **1**, wherein the second mode performs low pass filtering to remove the blocking artifacts.]

[**7**. The method as claimed in claim **1**, wherein the deblocking filtering in the default mode is performed by replacing the magnitude of the discontinuous component of pixels v_4 and v_5 that sandwich the block boundary with v_4' and v_5', according to the following equation:

$v_4'=v_4-d$

$v_5'=v_5+d$

$d=\text{CLIP}(c_2.(a_{3,0}'-a_{3,0})//c_3,0,(v_4-v_5)/2)*\delta(|a_{3,0}|<QP)$

$a_{3,0}'=\text{SIGN}(a_{3,0})*\text{MIN}(|a_{3,0}|,|a_{3,1}|,|a_{3,2}|)$

$a_{3,0}=([c_1 -c_2\ c_2 -c_1]*[v_3 v_4 v_5 v_6]^T)//c_3$

$a_{3,1}=([c_1 -c_2\ c_2 -c_1]*[v_1 v_2 v_3 v_4]^T)//c_3$

$a_{3,2}=([c_1 -c_2\ c_2 -c_1]*[v_5 v_6 v_7 v_8]^T)//c_3$,

where QP is the quantization parameter of the block containing the pixel v_5, values c_1, c_2, c_3 are kernel constants used in a DCT, and values of $a_{3,0}$, $a_{3,1}$, $a_{3,2}$ are the discontinuous component in each of the plurality of pixel sets, respectively.]

[**8**. The method as claimed in claim **7**, wherein c_1 and c_2 are approximated to an integer and c_3 is approximated to a multiple of 2, wherein the DCT is a 4-point DCT used to determine the frequency information, and wherein $a_{3,0}$, $a_{3,1}$, $a_{3,2}$ are evaluated from an inner product of the DCT kernel and the selected pixel set being S0, a first pixel set S1 and a second pixel set S2.]

[**9**. The method as claimed in claim **7**, wherein $|a_{3,0}|<QP$ prevents over-smoothing.]

[**10**. The method as claimed in claim **1**, further comprising performing the deblocking filtering process around horizontal and vertical block boundaries in a frame.]

[**11**. The method of claim **1**, wherein the removing blocking artifacts in the second mode satisfies the following equation:

$$v_n = \sum_{k=-4}^{4} b_k \cdot p_{n+k},\ 1 \le n \le 8$$

$$P_m=(|v_1-v_0<QP)?v_0:v_1,$$

if m<1;

v_m, if $1 \leqq m \leqq 8$;

$(|v_8-v_9|<QP)\ v_9:v_8$, if m>8;

$\{b_k: -4 \leqq k \leqq 4\}=\{1,1,2,2,4,2,2,1,1\}//16$,

where v_0-v_9 are boundary pixels, QP is the quantization parameter of a block adjacent the block boundary, and v_n is an adjusted pixel value.]

[**12**. The method of claim **1**, wherein the replacement pixel set contains a minimum magnitude of the at least one corresponding discontinuous component.]

[**13**. The method of claim **1**, wherein the first mode is the default mode and the second mode is the DC offset mode, and wherein each of the plurality of pixel sets has four pixels.]

[**14**. A method for removing blocking artifacts in a coding system comprising:

determining at least pixel sets S0, S1, S2 around a block boundary;

selecting one of a default mode and a DC offset mode as a deblocking mode based on an amount of blocking artifacts;

deblocking filtering of pixels adjacent the block boundary if the default mode is selected; and

removing artifacts in the DC offset mode, if the DC offset mode is selected and a DC offset mode condition is satisfied, wherein the artifacts are removed in the DC offset mode according to the following equation:

$$v_n = \sum_{k=-4}^{4} b_k \cdot p_{n+k},\ 1 \le n \le 8$$

$$P_m=(|v_1-v_0|<QP)?v_0:v_1,$$

if $m<1$;

v_m, if $1 \leqq m \leqq 8$;

$(|v_8-v_9|<QP)\ v_9:v_8$, if $m>8$;

$\{b_k: -4 \leqq k \leqq 4\}=\{1,1,2,2,4,2,2,1,1\}//16$,

where v_0-v_9 are boundary pixels, QP is the quanatation parameter of a block adjacent the block boundary, and v_n is an adjusted pixel value.]

[**15**. The method of claim **14**, wherein the deblocking filtering step comprises:

obtaining frequency information for each of the plurality of pixel sets S0, S1, S2;

replacing a magnitude of at least one discontinuous component in the frequency domain of a selected pixel set S0 of the plurality of pixel sets belonging to the block boundary with a magnitude of at least one corresponding discontinuous component belonging to a replacement pixel set S1, S2 of the plurality of pixel sets near the block boundary; and

applying the replaced frequency information of the selected pixel set S0 to the spatial domain to remove the blocking artifacts.]

[**16**. The method of claim **14**, further comprising determining a mode decision value, wherein the DC offset mode is selected if the mode decision value is greater than a first threshold value, wherein mode decision value is determined based on the following equation:

$$\text{mode decision value}=\phi(v_0-v_1)+\phi(v_1-v_2)+\phi(v_2-v_3)+\phi(v_3-v_4)+\phi(v_4-v_5)+\phi(v_5-v_1)+\phi(v_7-v_8)+\phi(v_8-v_9),$$

wherein $\phi(\gamma)=1$ when $|\gamma| \leqq$ a second threshold value and $\phi(\gamma)=0$ otherwise, and wherein v_0-v_9 are boundary pixel values.]

[**17**. The method of claim **14**, wherein the DC offset mode condition is satisfied when an absolute value of a maximum data value minus a minimum data value in block boundary pixels is smaller than 2QP, wherein the maximum data value=MAX(v_1, v_2, v_3, v_4, v_5, v_6, v_7, v_8), the minimum data value=MIN(v_1, v_2, v_3, v_4, v_5, v_6, v_7, v_8), QP is the quantization parameter of a block adjacent the block boundary and v_1-v_8 are the block boundary pixels.]

[**18**. The method of claim **14**, wherein the deblocking filtering in the default mode is performed by replacing the magnitude of the discontinuous component of pixels v_4 and v_5 sandwiching the block boundary with v_4' and v_5', according to the following equation:

$$v_4'=v_4-d$$

$$v_5'=v_5+d$$

$$d=CLIP(c_2.(a_{3,0}'-a_{3,0})//c_3,0,(v_4-v_5)/2)*\delta(|a_{3,0}|<QP)$$

$$a_{3,0}'=SIGN(a_{3,0})*MIN(|a_{3,0}|,|a_{3,1}|,|a_{3,2}|)$$

$$a_{3,0}=([c_1-c_2\ c_2-c_1]*[v_3v_4v_5v_6]^T)//c_3$$

$$a_{3,1}=([c_1-c_2\ c_2-c_1]*[v_1v_2v_3v_4]^T)//c_3$$

$$a_{3,2}=([c_1-c_2\ c_2-c_1]*[v_5v_6v_7v_8]^T)//c_3,$$

where QP is the quantization parameter of the block containing the pixel v_5, values c_1, c_2, c_3 are kernel constants used in a 4-point DCT, and values of $a_{3,0}$, $a_{3,1}$, $a_{3,2}$ are based on a simple inner product of the DCT kernel and the selected pixel set S0, a first pixel set S1 and the second pixel set S2.]

[**19**. The method of claim **14**, further comprising performing the determining through removing steps for each horizontal and vertical block boundaries in a frame.]

20. A method for removing blocking artifacts in a coding system comprising:

determining at least pixel sets S0, S1, S2 around a block boundary;

selecting one of a default mode and a DC offset mode as a deblocking mode based on an amount of blocking artifacts;

deblocking filtering of pixels adjacent the block boundary based on frequency information of the pixels adjacent to the bock boundary, if the default mode is selected; and

removing artifacts in the DC offset mode, if the DC offset mode is selected and a DC offset mode condition is satisfied, wherein the artifacts are removed in the DC offset mode according to the following equation:

$$v_n = \sum_{k=-4}^{4} b_k \cdot p_{n+k},\ 1 \le n \le 8$$

$$P_m = (|v_1 - v_0| < QP)?v_0:v_1,$$

if $m<1$;

v_m, *if* $1 \leqq m \leqq 8$;

$(|v_8-v_9|<QP)?v_9:\ v_8$, *if* $m>8$;

$\{b_k: -4 \leqq k \leqq 4\}=\{1,1,2,2,4,2,2,1,1\}//16$

wherein v_0-v_9 *are boundary pixels, QP is the quantization parameter of a block adjacent the block boundary, and* v_n *is an adjusted pixel value,*

wherein b_k *and* p_{n+k} *are variables used to calculate the adjusted pixel value* v_n *where n is an integer among 1, 2, 3, 4, 5, 6, 7, and 8,*

wherein b_k *changes according to a value of k where k is one of −4, −3, −2, −1, 0, 1, 2, 3, 4,*

wherein p_{n+k} *is decided according to* p_m *where m=n+k and m is an integer,*

wherein P_m *is one of boundary pixels values* v_0 *to* v_9 *according to given conditions of* $(|v_1-v_0|<QP)$ *and* $(|v_8-v_9|<QP)$ *and a value of m.*

21. The method of claim 20, wherein the deblocking filtering step comprises:

obtaining frequency information for each of the plurality of pixel sets S0, S1, S2;

replacing a magnitude of at least one discontinuous component in the frequency domain of a selected pixel set S0 of the plurality of pixel sets belonging to the block boundary with a magnitude of at least one correspond-

ing discontinuous component belonging to a replacement pixel set S1, S2 of the plurality of pixel sets near the block boundary; and

applying the replaced frequency information of the selected pixel set S0 to the spatial domain to remove the blocking artifacts.

22. The method of claim 20, futher comprising determining a mode decision value, wherein the DC offset mode is selected if the mode decision value is greater than a first threshold value, wherein mode decision value is determined based on the following equation:

$$\text{mode decision value}=\phi(v_0-v_1)+\phi(v_1-v_2)+\phi(v_2-v_3)+\phi(v_3-v_4)+\phi(v_4-v_5)+\phi(v_5-v_1)+\phi(v_7-v_8)+\phi(v_8-v_9),$$

wherein $\phi(\gamma)=1$ when $|\gamma|\leqq$ a second threshold value and $\phi(\gamma)=0$ otherwise,

wherein v_0-v_9 are boundary pixel values, and

wherein $\phi(\gamma)$ is a function generating 1 or 0 according to $|\gamma|$ and γ is a variable denoting a result of substraction of two given boundary pixel values.

23. The method of claim 20, wherein the DC offset mode condition is satisfied when an absolute value of a maximum data value minus a minimum data value in block boundary pixels is smaller than 2QP, wherein the maximum data value$=MAX(v_1, v_2, v_3, v_4, v_5, v_6, v_7, v_8)$, the minimum data value$=MIN(v_1, v_2, v_3, v_4, v_5, v_6, v_7, v_8)$, QP is the quantization parameter of a block adjacent the block boundary, and v_1-v_8 are the block boundary pixels.

24. The method of claim 20, wherein the deblocking filtering in the default mode is performed by replacing the magnitude of the discontinuous component of pixels v_4 and v_5 sandwiching the block boundary with v_4' and v_5', according to the following equation:

$$v_4'=v_4-d$$

$$v_5'=v_5+d$$

$$d=CLIP(c_2\cdot(a_{3,0}'-a_{3,0})//c_3,0,(v_4-v_5)/2)*\delta(|a_{3,0}|<QP)$$

$$a_{3,0}'=SIGN(a_{3,0})*MIN(|a_{3,0}|,|a_{3,1}|,|a_{3,2}|)$$

$$a_{3,0}=([c_1-c_2\ c_2-c_1]*[v_3v_4v_5v_6]^T)//c_3$$

$$a_{3,1}=([c_1-c_2\ c_2-c_1]*[v_1v_2v_3v_4]^T)//c_3$$

$$a_{3,2}=([c_1-c_2\ c_2-c_1]*[v_5v_6v_7v_8]^T)//c_3,$$

where QP is the quantization parameter of the block containing the pixel v_5, values c_1, c_2, c_3 are kernel constants used in a 4-point DCT, and values of $a_{3,0}$, $a_{3,1}$, $a_{3,2}$, are based on a simple inner product of the DCT kernel and the selected pixel set S0, a first pixel set S1 and the second pixel set S2,

wherein $a_{3,0}$, $a_{3,1}$, and $a_{3,2}$ represent DCT coefficients of corresponding pixel sets,

wherein d is a variable used to calculate v_4' and v_5' and denotes a result of a function CLIP (x, p, q) where x, p, and q are integers,

wherein the function CLIP (x, p, q) clips x to a value between p and q,

wherein δ(condition) is a function generating 1 if the "condition" is true and generating 0 if the "condition" is not true,

wherein T denotes a transpose of vector matrix, and

wherein v_1, v_2, v_3, v_4, v_5, v_6, v_7, and v_8 denote boundary pixel values.

25. The method of claim 20, further comprising performing the determining through removing steps for each horizontal and vertical block boundaries in a frame.

26. The method of claim 20, further comprising dividing a picture into blocks that each include multiple pixels, wherein the pixels of a first block are separated from pixels of a neighboring second block by the block boundary,

wherein deblocking filtering of the pixels adjacent to the block boundary further comprises adjusting a first pixel of the first block based upon a neighboring second pixel of the second block.

27. The method of claim 26,

wherein adjusting the first pixel further comprises replacing a pixel value v_3 of the first pixel with a value v_3',

wherein the value v_3' is expressed as:

$$v_3'=v_3-d,$$

wherein d is expressed as:

$$d=CLIP\left(c_2(a_{3,0}'-a_{3,0})//c_3,\ 0,\ \frac{(v_\varepsilon-v_4)}{2}\right)*\delta(|a_{3,0}|<QP),$$

wherein $a_{3,0}'$ is expressed as:

$$a_{3,0}'=SIGN(a_{3,0})*MIN(|a_{3,0}|,|a_{3,1}|,|a_{3,2}|),$$

wherein QP represents a quantization paramter of the second block, c_2, and c_3 represent DCT kernel coefficients, and v_4 represents a pixel value of the neighboring second pixel,

wherein $a_{3,0}$, $a_{3,1}$, and $a_{3,2}$, represent DCT coefficients of corresponding pixel sets,

wherein d is a variable used to calculate v_3' and denotes a result of a function CLIP (x, p, q) where x, p, and q are integers,

wherein the function CLIP (x, p, q) clips x to a value between p and q, and

wherein δ(condition) is a function generating 1 if the "condition" is true and generating 0 if the "condition" is not true.

28. The method of claim 26, wherein $\delta(|a_{3,0}|<QP)=1$ if $|a_{3,0}|<QP$, and wherein $\delta(|a_{3,0}|<QP)=0$ if $|a_{3,0}|\geqq QP$,

wherein $a_{3,0}$ represents a DCT coefficient of a corresponding pixel set, and

wherein δ(condition) is a function generating 1 if the "condition" is true and generating 0 if the "condition" is not true.

29. The method of claim 26, wherein c_2 is an interger and c_3 is a multiple of 2.

30. The method of claim 26, wherein $c_2=5$ and $c_3=8$.

31. The method of claim 26, further comprising applying the adjusting operation to a spatial domain of the first pixel.

32. The method of claim 26, wherein the block boundary is a vertical or horizontal block boundary.

33. The method of claim 26, further comprising adjusting the neighboring second pixel based upon frequency information of the first pixel.

34. The method of claim 26, wherein the magnitude of the adjusting operation is constrained to be no greater than half of the difference between a value of the first pixel and a value of the second pixel, using a clipping function.

35. The method of claim 26, wherein the magnitude of the adjusting operation is based upon a simple inner product of a DCT kernel and the first and second pixels.

36. The method of claim 26, wherein the magnitude of the adjusting operation is based upon a minimum magnitude of frequency information of the first and second pixels.

37. The method of claim 26, wherein the magnitude of the adjusting operation is based upon frequency information of the first pixel and the neighboring second pixel.

38. The method of claim 26, further comprising obtaining the frequency information for the neighboring second pixel, wherein the first pixel is adjusted if a magnitude of the blocking artificat is less than a quantization parameter of the second block.

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