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(71) Applicant *(for all designated States except US)*: **EWHA UNIVERSITY-INDUSTRY COLLABORATION FOUNDATION** [KR/KR]; Ewha University, 11-1 Daehyeon-dong, Seodaemun-gu, Seoul 120-750 (KR).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **LEE, Byung-Uk** [KR/KR]; 404-1202 Worldcup Park Apt., Sangam-dong, Mapo-gu, Seoul 121-830 (KR). **YANG, Se Jung** [KR/KR]; 1017, Tower Palace E dong, Dogok-dong, Gangnam-gu, Seoul 135-535 (KR).

(74) Agent: **TAEDONG INTERNATIONAL PATENT LAW FIRM**; 302, Daelim Office Valley, 97-3 Guro-dong, Guro-gu, Seoul 152-050 (KR).

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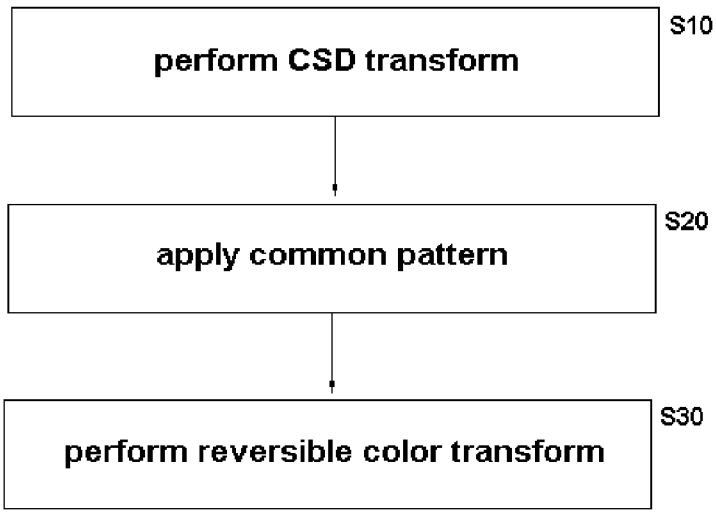
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(54) **Title**: A METHOD FOR REVERSIBLE COLOR TRANSFORM USING CANONICAL SIGNED DIGIT

[Fig. 1]



(57) **Abstract**: A method for reversible color transform using a canonical signed digit (CSD) is disclosed. The method includes (1) transforming respective color coordinate coefficients to CSD numbers; (2) extracting a common pattern from the CSD numbers and previously performing computation with respect to the common pattern; and (3) performing a reversible color transform, using the previously computed result. The method can enhance the speed of invertible integer color transform as a canonical signed digit (CSD) system and a common pattern technique are applied to the invertible integer color transform which can precisely implement an inverse transform matrix without causing a rounding-off error according to integerization.

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Description

A METHOD FOR REVERSIBLE COLOR TRANSFORM USING CANONICAL SIGNED DIGIT

Technical Field

[1] The present invention relates to color transform. More particularly, this invention relates to a method for reversible color transform (RCT) that can enhance the speed of invertible integer color transform as a canonical signed digit (CSD) system and a common pattern technique are applied to the invertible integer color transform which can precisely implement an inverse transform matrix without causing a rounding-off error according to integerization.

Background Art

[2] A color coordinate system for displaying standard colors is used to process color images for various purposes. Color coordinate systems include RGB, CMY, HSI, YUV, YC_bC_r, etc. Color transform used for performing transformation between color coordinate systems is composed of a 3x3 matrix. If color transform is implemented via a general fixed-point processor, approximate values for color coordinate coefficients are used. This causes a rounding error and makes it impossible to precisely implement an inverse transform matrix.

[3] Technology has been developed to overcome the disadvantages of the fixed-point processor. Recently, an invertible integer color transform was developed by Pei, et al. The reversible integer color transform has an advantage in that it can precisely implement an inverse transform matrix without causing a rounding-off error according to integerization, but its performance speed needs to be enhanced.

Disclosure of Invention

Technical Problem

[4] The present invention solves the above problems, and provides a method for reversible color transform that can enhance the speed of invertible integer color transform as a canonical signed digit (CSD) system and a common pattern technique are applied to the invertible integer color transform which can precisely implement an inverse transform matrix without causing a rounding-off error according to integerization.

Technical Solution

[5] In accordance with an exemplary embodiment of the present invention, the present invention provides a method for reversible color transform using canonical signed digit (CSD), including: (1) transforming respective color coordinate coefficients to CSD numbers; (2) extracting a common pattern from the CSD numbers and previously

performing computation with respect to the common pattern; and (3) performing a reversible color transform, using the previously computed result.

[6] Preferably, the CSD numbers are a set of ternary number composed of the digits -1, 0, and +1. There is no case where both numbers at successive CSD digits are not zero.

[7] Preferably, the extraction and the computation includes extracting a common pattern from all of the CSD numbers.

[8] Preferably, the reversible color transform is an invertible integer color transform.

Advantageous Effects

[9] As described above, the method for reversible color transform, according to the present invention, can enhance the speed of invertible integer color transform as a canonical signed digit (CSD) system and a common pattern technique are applied to the invertible integer color transform which can precisely implement an inverse transform matrix without causing a rounding-off error according to integerization.

Brief Description of Drawings

[10] The features and advantages of the present invention will become more apparent from the following detailed description in conjunction with the accompanying drawings, in which:

[11] Figure 1 shows a flow chart describing a method for reversible color transform according to an embodiment of the present invention;

[12] Figure 2 shows a table where the last four of the total eight coefficients in a matrix transforming from a RGB color coordinate system to a UVW color coordinate system are expressed as a CSD format;

[13] Figure 3 shows a table where common patterns are expressed using all eight transform coefficients; and

[14] Figure 4 shows a table where common patterns are expressed using various types of color transform coefficients.

[15] <Brief Description of Symbols in the Drawings>

[16] S10: perform CSD transform

[17] S20: apply common pattern technique

[18] S30: perform reversible color transform

Best Mode for Carrying out the Invention

[19] Hereinafter, exemplary embodiments of the present invention are described in detail with reference to the accompanying drawings.

[20] Figure 1 shows a flow chart describing a method for reversible color transform according to an embodiment of the present invention. As shown in Figure 1, the method includes performing a canonical signed digit (CSD) transform (S10), applying a common pattern technique (S20), and performing a reversible color transform (S30).

[21] At step S10, respective color coordinate coefficients are transformed to CSD numbers. A CSD system can minimize non-zero numbers and thus reduce the frequency of addition in the hardware multiplier. The encoding system of the CSD system is based on a set of ternary numbers composed of the digits -1, 0, and +1. There is no case where both numbers at successive CSD digits are not zero. That is, this case can be expressed by an equation, $c_i \times c_i = 0$ (c_i denotes the i-th CSD digit). Therefore, if the binary number of N bits is transformed to CSD numbers, the CSD system has less than the (N+1)/2 of non-zero numbers and thus does not need to find the frequency of the number in order to perform multiplication. An estimated value for the number of non-zero numbers at CSD numbers is asymptotically converged to N/3 + 1/9. The CSD number has 33% less non-zero numbers, on the average, than the binary number. Table 1 below shows an example where the binary number of N=4 is transformed to the CSD number. In Table 1, * is indicative of -1. When the binary number is transformed to the CSD number, as described in Table 1, it is ascertained that, with respect to negative numbers, the number of non-zero numbers at the binary number is less than the number of non-zero numbers at the CSD number, and the number 1 is reduced from the total number of 32 to 23.

[22] Table 1

[Table 1]

[Table]

Number	2's complement	CSD
0.875	0111	100*
0.750	0110	10*0
0.625	0101	0101
0.500	0100	0100
0.375	0011	010*
0.250	0010	0010
0.125	0001	0001
0	0000	0000
-0.125	1111	000*
-0.250	1110	00*0
-0.375	1101	0*01
-0.500	1100	0*00
-0.625	1011	0*0*
-0.750	1010	*010
-0.875	1001	*001
-1	1000	*000

[23] At step S20 in Figure 1, a common pattern is extracted from coefficients of CSD numbers which were transformed at S10 and then previously computed. The present invention employs a common pattern technique to reduce the numbers of adder and subtractor for CSD numbers. As a common pattern is extracted from all CSD coefficients and previously computed by the application of the common pattern technique, the numbers of addition and subtraction can be reduced. When a common pattern is used in hardware of a plurality of multipliers, the total amount of computation can be reduced by 50%.

[24] Figure 2 shows a table where the last four of the total eight coefficients in a matrix transforming from a RGB color coordinate system to a UVW color coordinate system are expressed as a CSD type. In color transform, respective multiplications can be expressed as $g_i \cdot x$, where g_i denotes the matrix coefficients in one column ($i = 1, ..., 8$) and x denotes binary input, 1 or 0. If respective coefficients are expressed as the CSD format, such as $g_i = g_{i0}g_{i1}g_{iM-1}$ (M is the total bit length), the multiplication is expressed

by following Math Figure 1.

[25] MathFigure 1

[Math.1]

$$\sum_{j=0}^{M-1} g_{ij} \cdot (x >> j)$$

[26] As shown in the table of Figure 2, the same circle has the same common pattern at the respective coefficients. Arithmetic operations for g_5 to g_8 in table of Figure 2 are expressed as the following Math Figure 2,

[27] MathFigure 2

[Math.2]

$$g_5 \cdot x = -x + x << 2$$

$$g_6 \cdot x = -x << 3 + x << 5$$

$$g_7 \cdot x = x + x << 3 + x << 6$$

$$g_8 \cdot x = x + x << 2 + x << 5$$

[28] Where, x << a means that x is shifted left a times (left shift). A common pattern for the four coefficients is 10* (indicated by the solid line circle) and 100* (indicated by the dotted line circle) and can be defined as the following Math Figure 3.

[29] MathFigure 3

[Math.3]

$$w_1 = -x + x << 2,$$

$$w_2 = -x + x << 3$$

[30] Using Math Figure 3, Math Figure 2 can be expressed as the following Math Figure 4.

[31] MathFigure 4

[Math.4]

$$g_5 = w_1$$

$$g_6 = w_1 << 3$$

$$g_7 = x + w_2 << 3$$

$$g_8 = x + w_2 << 2$$

[32] By comparing Math Figure 4 with Math Figure 2, it can be ascertained that the number of addition is reduced from 9 to 5 by using the common patterns, w_i.

[33] Figure 3 shows a table where common patterns are expressed by using all eight transform coefficients. As shown in the table of Figure 3, when the transform coefficients are expressed by the binary number, the total number of addition is 33. On the contrary, when the transform coefficients are transformed to the CSD format and shared with common patterns, the total number of addition is reduced to 16. The reduction rate is larger if all eight coefficients in the table of Figure 3 are used than if only four coefficients in the table of Figure 2 are used. Through this result, it can be ascertained that a higher number of coefficients in the common pattern technique and an increased rate of multiplication produces a more effective performance.

[34] Figure 4 shows a table where common patterns are expressed in terms of various kinds of color transform coefficients. As shown in the table of Figure 4, a common pattern technique is applied to transform coefficients when an RGB color coordinate is transformed to a KLA color coordinate; RGB to IV_1V_2; RGB to YC_bC_r; RGB to DCT; RGB to YIQ; RGB to XYZ; and RGB to UVW.

[35] At step S30 in Figure 1, a reversible color transform is performed using the result that was previously computed for the common pattern at S20. As described above, the reversible color transform is an invertible integer color transform.

[36] Table 2 below shows the computation rates for respective reversible color transformations by comparing therewith. As shown in Table 2, compared with the conventional reversible color transform (or a transformation using 2's complement), the reversible color transform according to the present invention, i.e., a transformation using a CSD number and a common pattern, can reduce the number of adders by approximately 40~65%.

[37] Table 2

[Table 2]

[Table]

	RGB -> KLA	RGB -> IV_1V_2	RGB -> YC_BC_R	RGB -> DCT	RGB -> YIQ	RGB -> XYZ	RGB -> UVW
Number of adders in 2's complement	50	42	31	34	34	33	33
Number of adders in CSD	18	19	17	20	18	20	16
Reduction rate	64.0%	54.8%	45.2%	41.2%	47.1%	39.4%	51.5%

[38] Although preferred embodiments of the present invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications,

additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims.

Claims

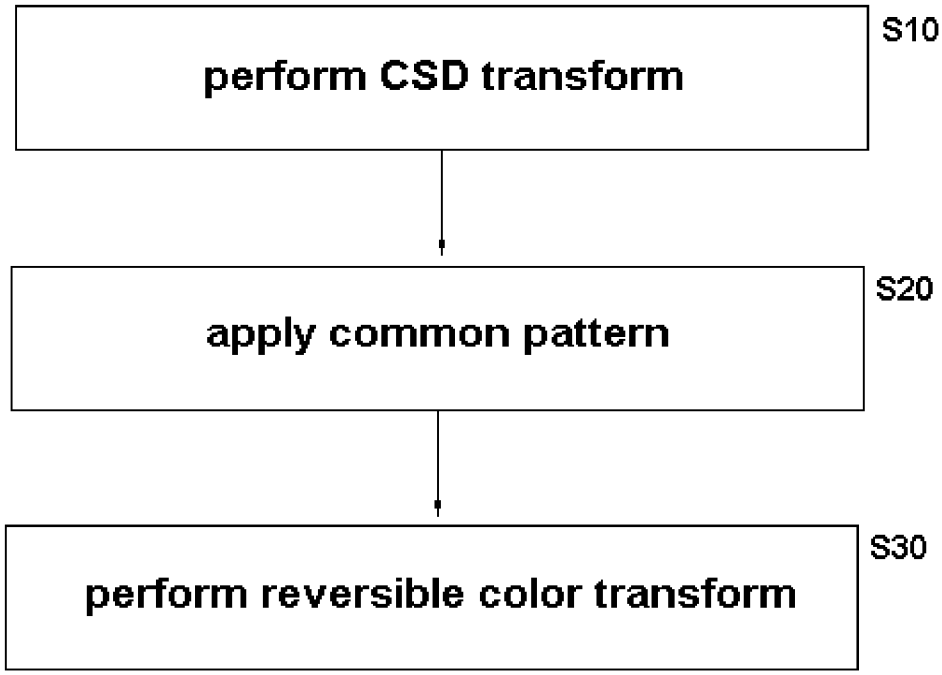
[1] A method for reversible color transform using canonical signed digit (CSD), comprising:
(1) transforming respective color coordinate coefficients to CSD numbers;
(2) extracting a common pattern from the CSD numbers and previously performing computation with respect to the common pattern; and
(3) performing a reversible color transform, using the previously computed result.

[2] The method according to claim 1, wherein:
the CSD numbers are a set of ternary number composed of the digits -1, 0, and +1; and
there is no case where both numbers at successive CSD digits are not zero.

[3] The method according to claim 1, wherein the extraction and the computation comprises:
extracting a common pattern from all of the CSD numbers.

[4] The method according to claim 1, wherein the reversible color transform is an invertible integer color transform.

[Fig. 1]



[Fig. 2]

	2^{0}	2^{-1}	2^{-2}	2^{-3}	2^{-4}	2^{-5}	2^{-6}	2^{-7}
g_5	0	0	0	0	0	1	0	*
g_6	0	0	1	0	*	0	0	0
g_7	0	1	0	0	*	0	0	1
g_8	0	0	1	0	0	*	0	1

[Fig. 3]

2's complement	# of 1's	CSD	# of 1's	CSD	# of 1's
11011010	5	00*0*010	3	00*0*010	3
01111111	7	1000000*	2	1000000*	2
01000110	3	010010*0	3	01001*0	2
11100111	6	00*0100*	3	00*0100*	3
00000011	2	0000010*	2	000001*0	1
00110000	2	010*0000	2	010*0000	1
00111001	4	0100*001	3	0100*001	2
00011101	4	00100*01	3	00100*01	2
total	33	total	21	total	16

[Fig. 4]

	RGB to KLA	RGB to IV_1V_2	RGB to YC_BC_R	RGB to DCT	RGB to YIQ	RGB to XYZ	RGB to UVW
g_1	00*010*0*	0100*010*	00100100	010*01010	00010001 0	01010010	00*0*010
g_2	101001000	0010*000*	001010101	001010001	0100*0001	0*010100*	1000000*
g_3	00*010*0*	00*0*0*0*	00010*000	00100*001	00*0*000*	10*010*01	010010*0
g_4	100*00*01	0*010*000	*01010 10*	*01010*0*	0*0010010	00100100*	00*0100*
g_5	*00101010	100000000	0*000*00*	0*010*000	*010*0*01	010*0000*	00000 10*
g_6	100000101	0100 10*01	000*00001	00*00010*	0100*0010	000*00101	010*0000
g_7	000*00*0*	000100*01	0010*0010	010*01010	010*010*0	*0*0*0*0*	0100*001
g_8	00000000*	0*00*0101	000*0*001	001010001	000*00001	100*00100	00100*01

INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER

H04N 9/67(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC H04N, G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean Utility models and applications for Utility models since 1975
Japanese Utility models and applications for Utility models since 1975

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKIPASS, SEARCH TERMS: CANONICAL, SIGN, and similar terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR 10-1996-0002049 A (SAMSUNG ELECTRONICS CO., LTD.), 26 January 1996 See abstract, claim1	1-4
A	US 5623318 A (MYEONG-HWAN LEE), 22 April 1997 See abstract, column2, lines 8-59	1-4
A	JP 2005-217798 A (SEIKO EPSON CO., LTD.), 11 August 2005 See abstract, claim1	1-4
A	US 2007-0013926 A1 (MIYATA YUJI), 18 January 2007 See abstract	1-4

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
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Government Complex-Daejeon, 139 Seonsa-ro, Seo-gu, Daejeon 302-701, Republic of Korea
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Authorized officer
SHIN, Jae Chul
Telephone No. 82-42-481-8215

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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