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Line-Adaptive Color Transforms for Lossless Frame Memory Compression

Joungeun Bae[1] and Hoon Yoo[2]*

[1]Department of Computer Science, SangMyung University, Jongno-gu, Seoul, South Korea.
[2]Full Professor, Department of Electronics, SangMyung University, Jongno-gu, Seoul, South Korea.
**Corresponding author*

Abstract

This paper proposes line-adaptive color transforms for lossless frame memory compression. Line-based compression methods are necessary for reducing memory requirement for display devices. A color transform is not included in the existing lossless frame memory compression based on the modified Hadamard Transform (MHT) and adaptive Golomb-Rice (AGR) coding. To achieve the better coding efficient for a line-based lossless compression, a method of line-adaptive color transforms is essential. By applying a lossless color transform with the best compression ratio in each line, it achieves higher compression efficiency. This paper describes the analysis of eight color transforms in terms of compression performance for the proposed method. Experimental results show that the proposed method provides reduced bitrate compared with the existing method without a color transform.

Keywords: Lossless compression, Line-adaptive color transforms, Display devices

INTRODUCTION

Compression is an essential technique for storing and transmitting high-quality images. Especially, a low-complexity compression becomes mandatory for overcoming the limited resources of 3-dimensional display devices [1-4]. Compression methods are classified as lossy and lossless. The lossy compression causes irretrievable quality loss. Thus, the lossless compression is appropriate for the display devices because it gives priority to image quality.

Several frame compression methods have been addressed to reduce the computational-complexity of display devices. Block-based frame compression methods have been proposed which are also used in video coding standards [5-13]. However, the frame memory in display devices is transmitted line by line. Using these methods to process display frames cause extensive memory traffic.

Thus, line-based lossless compressions for display frames have been addressed [14-17]. Among those studies, lossless compression for LCD devices has been proposed for the first time [14]. This method uses 8-point MHT for band separation and AGR for entropy coding. This method provides a good performance in terms of compression ratio [17].

However, this method does not include a color transform in a preprocessing step. The color transform for compression algorithms improves compression ratio by converting redundant components in the RGB to less correlated components. Thus, a method of applying a color transform to existing method has been proposed [18]. However, for line-by-line processing, applying different color transforms to each line is better than applying a single-color transform to entire image. Therefore, this paper proposes a method to apply different color transforms to each line. This method is defined as line-adaptive color transforms and is depicted in Fig.1.

Normally RGB components are converted to one luminance and two chrominances through a color transform. During a color transform, a component range expands, which means that the number of bits required to store the transformed pixel increases. Thus, it is necessary to consider the component range expansion when applying line-adaptive color transforms to the existing method.

In this paper, we propose line-adaptive color transforms for a lossless frame memory compression providing a line based processing. In the proposed method, a color transform with the best compression ratio is applied to each line. Line-adaptive color transforms include eight lossless color transforms and they are analyzed in this paper. Analysis of color transforms describes that the proposed method can lead to better compression by reducing the correlation of RGB components. Experimental results confirmed that the proposed method gives a shorter bitrate comparable with the existing method

LOSSLESS COLOR TRANSFORM

Karhunen-Loeve Transform (KLT) is well known as a method for optimally reducing the correlation of color components. However, applying KLT to compression is not suitable because of a high-computational complexity. Thus, color transforms based on KLT have been proposed. Color transforms must be an integer-reversible so that they can be conducted in the lossless frame compression. Furthermore, an analysis of a component range expansion and a complexity of transforms is required to predict the efficiency of the proposed method. The forward and inverse transforms of each of the eight color transforms are shown in Table 1.

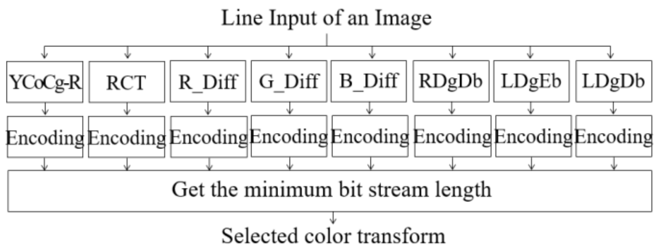

Figure 1. Line-adaptive color transforms.

The YCoCg-R is a color transform used in the JPEG-XR [19]. Each component of RGB is converted into Y, which is a luminance and Co, Cg, which are chrominance respectively.

The YCoCg-R approximated to KLT, calculates a green channel at the highest ratio, considering a human perception. In this transform, one bit of component range expansion occurs in a chrominance. In terms of a complexity, there are four adders and a one shift operator per pixel.

The RCT is used in JPEG 2000 [20]. Each component of R, G and B is transformed into Y, Cu and Cv respectively. A one bit of a component range expansion occurs in a chrominance component. Four add operators and two shift operators are required per pixel, in terms of a computational complexity.

To reduce a complexity, there are very simple color transforms that substract primary colors, defined as A2, A6 and A7 [21]. In these transforms, a luminance is a primary color and chrominances are subtraction of remaining colors and a luminance. In this paper, we refer to these transforms as R-Diff, G-Diff and B-diff. They simply have only two adders.

Similarly, a RDgDb is also very simple, with a luminance is R and chrominances are differences between adjacent colors [22]. As in the previous transforms, two adders are required, and a component range expansion is a one bit in a chrominance component.

Color transforms based on human vision have been proposed, and these are also composed of two adders, resulting in low complexity [22]. These methods consider a luminance response in real human vision systems. These methods also have a one bit of a component range expansion in a chrominance component.

Table. 1. Forward and inverse transformations

	Forward	Inverse
YCoCg-R	$Co = R - B$ $t = B + \lfloor Co/2 \rfloor$ $Cg = G - t$ $Y = t + \lfloor Cg/2 \rfloor$	$t = Y - \lfloor Cg/2 \rfloor$ $G = Cg + t$ $B = t - \lfloor Co/2 \rfloor$ $R = B + Co$
RCT	$Cv = R - G$ $Cu = B - G$ $Y = G + \lfloor (Cu + Cv)/4 \rfloor$	$G = Y - \lfloor (Cu + Cv)/4 \rfloor$ $R = Cv + G$ $B = Cu + G$
R_Diff	$Y = R$ $U = G - R$ $V = B - R$	$R = Y$ $G = U + R$ $B = V + R$
G_Diff	$Y = G$ $U = B - G$ $V = R - G$	$G = Y$ $B = U + G$ $R = V + G$
B_Diff	$Y = B$ $U = G - B$ $V = R - B$	$B = Y$ $G = U + B$ $R = V + B$
RDgDb	$R = R$ $Dg = R - G$ $Db = G - B$	$R = R$ $G = R - Dg$ $B = G - Db$
LDgEb	$Dg = R - G$ $L = R - \lfloor Dg/2 \rfloor$ $Eb = B - L$	$R = L + \lfloor Dg/2 \rfloor$ $G = R - Dg$ $B = Eb + L$
LDgDb	$Dg = R - G$ $L = R - \lfloor Dg/2 \rfloor$ $Db = G - B$	$R = L + \lfloor Dg/2 \rfloor$ $G = R - Dg$ $B = G - Db$

EXISTING METHOD

The existing method of a lossless frame memory compression is the method for a line-based processing and display devices [14]. The line data of an input image becomes a bit stream segment through this compression. In this method, 8-point MHT with a lifting scheme are used for decorrelation. The lifting scheme is well known for fast wavelet transforms [23]. A signal flow of the 8-point MHT is shown in Fig.2.

The overall flowchart of the existing method is illustrated in Fig. 3. This method conducts a total of two 8-point MHTs. After performing the first 8-point MHT, collect only the DC components and perform the one more 8-point MHT on them. This process provides better compression performance by reducing the correlation of DC components.

AC components are entropy coded through Adaptive Golomb-Rice (AGR). Rice mapping converts a negative number to a non-negative number since AGR coding can not process a negative number, defined as (1). AGR coding uses a different binary code of k for each line, which is the value that can maximize compression performance. The value of k is calculated as (2), where the length of k minimizes the sum of GR code lengths.

$$\mathrm{v} = \begin{cases} 2\mathrm{c}, & \mathrm{c} \geq 0 \\ -2\mathrm{c} - 1, & \mathrm{c} < 0 \end{cases} \quad (1)$$

$$\mathrm{length} = \mathrm{k} + 1 + \mathrm{v}/2^{\mathrm{k}} \quad (2)$$

The final step is packing as a bit stream, which is done in the following order. The value of k is packed with 3-bit fixed length coding (FLC) in the far-left position. Next, DC components are packed with 8-bit FLC and AC components packed with AGR code.

PROPOSED METHOD

In this paper, we apply line-adaptive color transforms to the existing method and propose modified methods accordingly. The method of line-adaptive color transforms is an algorithm to select the color transform with the best compression ratio for the input line data. When each encoding is applied after eight color transforms, a color transform with the shortest bit stream is selected.

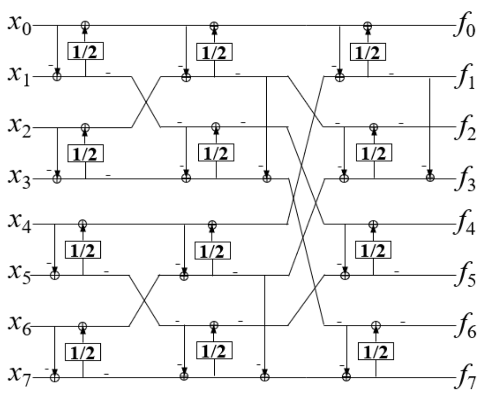

Figure 2. Signal flow of 8-point MHT.

With the selected color transform, U and V components include negative numbers when the RGB components are converted into YUV. It is not appropriate that the components of U and V are input as they are in the existing method, since the existing method only processes positive numbers.

The flowchart of the modified compression method to process the negative number of components of U and V is illustrated in Fig.4. Separating the band into two 8-point MHT is identical to the existing method. DC and AC of U and V are coded with AGR unlike DC are packed with FLC in the existing method. The existing method is defined as method1 and the modified method is defined as method2.

An overall flow chart of the proposed method is depicted in Fig.5. After performing the selected color transform, the method1 is performed for the value of Y and the method 2 is performed for the values of U and V. The process of band separation in entropy coding is shown in Fig.6. Fig. 6 (a) is the band separation of method 1 and Fig. 6 (b) is the band separation of method2. Fig. 6 (c) shows the whole band separation process when method 1 and method 2 are performed on the YUV components, respectively.

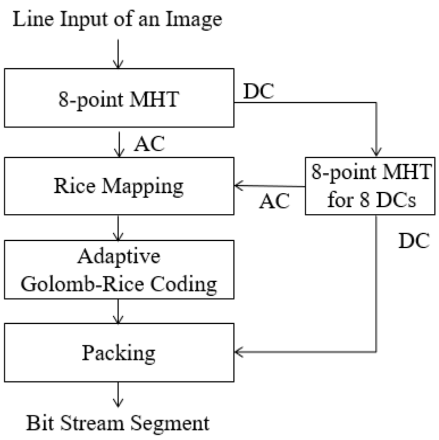

Figure. 3. Existing method for Y component (method1).

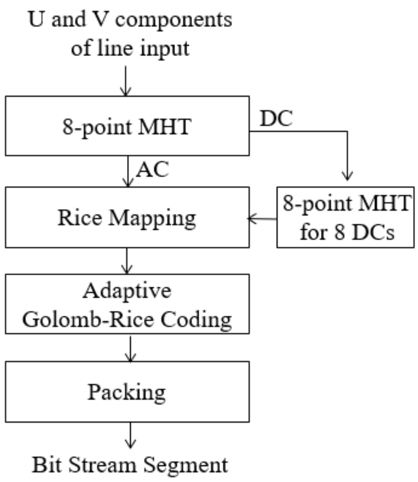

Figure 4. Modification for U and V components (method 2).

EXPERIMENTAL RESULTS

To evaluate the proposed method, the existing method of a lossless compression is compared with our algorithm. An experiment was conducted to obtain the bitrate of compressed data. The input images were fifteen images released for the compression study of color image by Kodak corporation. Table 1 shows the bitrate obtained by the existing method, the existing method with RCT and the proposed method. A bitrate is the value of compressed file length divided by the pixel size of an input image and defined as (3). It is a value indicating the number of bits required for one pixel. The bitrate of the uncompressed image is 24 bit/pixel.

$$\text{bitrate} = \frac{\text{Compressed bitdata size}}{\text{pixels}} \quad (3)$$

Experimental results show that the bitrate is the shortest when compressed with the line-adaptive color transform. The average bitrate of the proposed method was 20% shorter than that of the existing method. Also, the bitrate of the proposed method is shorter than the single-color transform applied to the whole image, that is, when the RCT is applied. This experiment shows that line-adaptive color transforms can improve compression performance by reducing correlation redundancy of RGB components in each line.

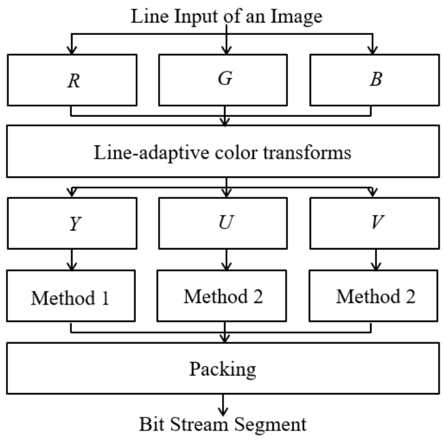

Figure. 5. Flowchart of the proposed method.

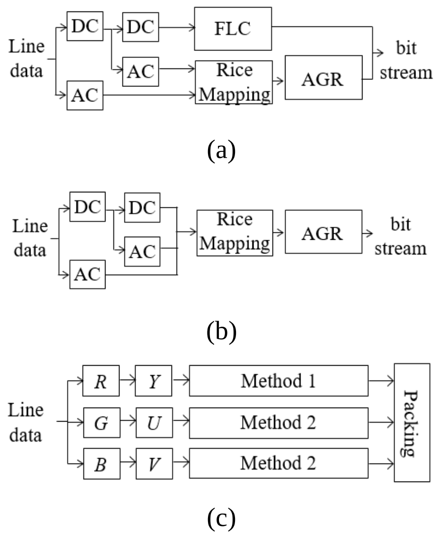

Figure. 6. Subband decomposition of the entropy coding. (a) method 1, (b) method 2, (c) proposed method

Table 2 shows the percentage of color transforms in each image when applying the proposed method to the image set. On average, the percentage of RCT was the highest. However, each image has different dominant color transformations. For example, overall, the occupancy of G_Diff and B_Diff are not high, but G_Diff is dominant in the 2nd image and B_Diff is dominant in the 15th image. This means that the compression ratio can be enhanced by applying the line-adaptive color transformations because the dominant color is different for each line and each image.

Table 1. Bitrate

Kodak	Existing method [14]	Existing method + RCT [18]	Proposed method
1	18.96	14.12	13.99
2	15.52	13.60	13.58
3	14.96	12.49	12.47
4	16.26	13.57	13.50
5	19.65	15.37	15.32
6	16.47	12.64	12.56
7	16.16	13.21	13.17
8	20.76	15.73	15.70
9	15.78	12.32	12.18
10	16.09	12.77	12.69
11	16.63	13.03	12.88
12	14. 87	12.31	12.15
13	19.77	14.88	14.74
14	17.67	13.98	13.95
15	17.21	14.25	14.08
average	17.12	13.62	13.53

Table 2. Percentage of transforms in line-adaptive color transforms

Kodak	YCoCg-R	RCT	R_Diff	G_Diff	B_Diff	RDgDb	LDgEb	LDgDb
1	9	2	8	0	0	51	31	0
2	1	39	0	48	0	0	0	13
3	5	61	10	1	5	1	13	4
4	1	27	0	4	18	24	2	26
5	39	33	0	0	1	11	16	0
6	29	25	6	0	2	9	25	3
7	2	42	7	7	0	2	28	12
8	26	34	0	1	0	34	4	1
9	34	16	1	0	0	3	43	2
10	49	16	1	0	0	9	22	3
11	31	18	0	3	21	9	16	2
12	4	3	6	0	0	25	61	1
13	6	22	33	2	0	18	19	1
14	9	60	0	2	0	9	14	6
15	7	3	0	0	66	15	8	0
average	17	27	5	4	8	15	20	5

CONCLUSION

This paper has proposed line-adaptive color transforms for lossless frame compression. The complexity and component range expansion of the eight lossless color transforms included in the proposed method are analyzed. The line-adaptive color transforms are applied to the lossless frame compression based on the analysis. Experimental results show that the proposed method can obtain a reduced bitrate than the existing method.

REFERENCES

[1] Y. Lee, and H. Yoo, "Low-cost 3D motion capture system using passive optical markers and monocular vision," Elsevier Optik, vol. 130, pp.1397-1407, Feb. 2017.

[2] Y. Lee, and H. Yoo, "Three-dimensional visualization of objects in scattering medium using integral imaging and spectral analysis," Elsevier Optics and Lasers in Engineering, vol. 77, no. 2, pp. 31-38, Feb. 2016.

[3] M. Ha, and H. Yoo, "Lossless Compression of 3D Geometry Data via Optimal Selection," International Journal of Applied Engineering Research, vol. 11, no. 21, pp. 10640-10643, Nov. 2016.

[4] M. Ha, and H. Yoo, "Preprocessing Using Classification for Lossless Compression of 3D Geometry Data," International Journal of Applied Engineering Research, vol. 11, no. 13, pp. 7947-7950, July 2016.

[5] S. H. Lee, M. K. Chung, S. M. Park, and C. M. Kyung, "Lossless frame memory recompression for video codec preserving random accessibility of coding unit," IEEE transactions on consumer electronics, vol.55, no. 4, Nov. 2009.

[6] J. Kim, J. Kim, and C. M. Kyung, "A lossless embedded compression algorithm for high definition video coding," Multimedia and Expo (ICME) 2009. IEEE International Conference on, pp.193-196, Jul. 2009.

[7] X. Bao, Z. Dajiang, and G. Satoshi, "A lossless frame recompression scheme for reducing DRAM power in video encoding," Circuits and Systems (ISCAS), Proceedings of 2010 IEEE International Symposium on. IEEE, pp.667-680, Jun. 2010.

[8] Yang. L, X. He, G. Zhang, L. Qing, and T. Che, "A low complexity block-based adaptive lossless image compression," Elsevier Optik-International Journal for Light and Electron Optics, vol. 124, no. 24, pp. 6545-6552, Dec. 2013

[9] D. Venugopal, S. Mohan, and S. Raja, "An efficient block based lossless compression of medical images," Elsevier Optik-International Journal for Light and Electron Optics, vol. 127, no. 2, pp. 754-758, Jan. 2016.

[10] S. Andriani, and G. Calvagno, "Lossless compression of color sequences using optimal linear prediction theory." IEEE Transactions on Image Processing, vol. 17, no. 11, pp. 2102-2111, Sep. 2008.

[11] D. Brunello, G. Calvagno, G. Z. Mian, and R. Rinaldo, "Lossless compression of video using temporal information," IEEE Transactions on Image Processing, vol. 12, no. 2, pp. 132-139, Apr. 2003.

[12] J. Lei, X. Zou, Z. Wu and W. Fan, "Research of an image map encoding algorithm on frame buffer," ASIC, 2007. ASICON'07. 7th International Conference on. IEEE, pp. 894-897, Oct. 2007.

[13] X. Lian, Z. Liu, W. Zhou, and Z. Duan, "Lossless frame memory compression using pixel-grain prediction and dynamic order entropy coding," IEEE Transactions on Circuits and Systems for Video Technology, vol. 26, no. 1, pp. 223-235, Aug. 2015.

[14] T. L. B. Yng, B. G. Lee, and H. Yoo, "A low complexity and lossless frame memory compression for display devices," IEEE transactions on consumer electronics, vol. 54, no. 3, pp. 1453-1458, Oct. 2008.

[15] H. T. Yang, J. W. Chen, H. C. Kuo, and Y. L. Lin, "An effective dictionary-based display frame compressor," Embedded Systems for Real-Time Multimedia, 2009. IEEE/ACM/IFIP 7th Workshop on. IEEE, Oct. 2009.

[16] S. Dikbas, and F. Zhai, "Lossless image compression using adjustable fractional line-buffer," Elsevier Signal Processing: Image Communication, vol. 25, no. 5, pp. 345-351, Jun. 2010.

[17] H. C. Kuo, and Y. L. Lin, "A hybrid algorithm for effective lossless compression of video display frames," IEEE Transactions on Multimedia, no. 14, vol. 3, pp.500-509, Jun. 2012.

[18] J. Bae, and H. Yoo, "Analysis of color transforms for lossless frame memory compression," International Journal of Applied Engineering Research, vol. 12, no. 24, pp. 15664-15667, Dec. 2017.

[19] H. S. Malvar, G. J. Sullivan, and S. Srinivasan, "Lifting-based reversible color transformations for image compression," Proc. SPIE, vol. 7073, 2008.

[20] C. Christopoulos, A. Skodras, and T. Ebrahimi, "The JPEG2000 still image coding system: an overview," IEEE transactions on consumer electronics, vol. 46, no. 4, pp. 1103-1127, Nov. 2000.

[21] T. Strutz, "Adaptive selection of colour transformations for reversible image compression," Signal Processing Conference (EUSIPCO), 2012 Proceedings of the 20th European. IEEE, 2012.

[22] R. Starosolski, "New simple and efficient color space transformations for lossless image compression," Elsevier Journal of Visual Communication and Image Representation, vol. 25, no. 5, pp. 1056-1063, Jul. 2014.

[23] H. Yoo, and J. Jeong, “Signal-dependent wavelet transform and application to lossless image compression,” Electronics Letters, 2002, vol. 38, no. 4, pp.170-172, Aug. 2002.