Extended JPEG Decoders With Luma Restoration and Luma-Guided Chroma Restorations

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***Abstract*—This study presents two extended JPEG decoders that restore the degraded images quickly and accurately. They have a luma restoration and two luma-guided chroma restorations before/after chroma upsampling in addition to the standard decoder. The experiments based on the typical classical methods such as the block-matching and 3D filtering (BM3D) and guided filter (GF) show that the proposed methods restore the noise-added JPEG-compressed images faster and better than the classical one that does not consider the JPEG process.**

***Index Terms*—image restoration, JPEG, luma, chroma**

I. Introduction

With the development of multimedia devices and broadband networks, image compression is one of the most necessary technologies and it should be noted that the JPEG is still the de-facto image coding standard. However, when the JPEG compresses an image at a low bitrate, various annoying artifacts may appear on the textures and colors. As one of the most known them, the blocking is appeared due to the discontinuity generated with the DCT and quantization in each 8×8/16×16 block. As the other one, the color bleeding is caused because the decoder upsamples the chroma downsampled on the encoder forcibly.

Although many images are commonly compressed with the JPEG as described above, some high-precision image restoration algorithms [1], [2] tend to observe only the resulting images and do not consider the JPEG process sufficiently. As a result, the conflicts between the conventional ones and the JPEG process may other undesirable artifacts. Also, many of algorithms that consider the JPEG process [3], [4] still involve some redundant processes, i.e., the restoration after whole decoding.

To reduce such artifacts and redundancies, this study presents two extended JPEG decoders inspired by a joint bilateral filter (JBF) for color debleeding in [5]. The proposed methods have a luma restoration (LR) and two luma-guided chroma restorations (CRs) before/after chroma upsampling in addition to the standard decoder. Only adding new simple algorithms directly to the existing decoder not only eliminates many of the redundant processes, which are required in the conventional methods, but also improves the restoration performance. The experiments based on the typical classical algorithms such as the block-matching and 3D filtering (BM3D) [6] and guided filter (GF) [7] show that the proposed methods restore the noise-added JPEG-compressed images faster and better than the classical one that does not consider the JPEG process.

II. Preliminaries

A. JPEG Decoder

The JPEG decoder consists of the following steps:

1) Decimalize the bitstream into the quantized DCT coefficients.
2) Dequantize the quantized DCT coefficients.
3) Convert the coefficients in the spectral domain into one luma Y and two chromas C_b and C_r in the spatial one.
4) Upsample the C_b and C_r downsampled on the encoder with the default sampling factor $[4:2:0]$ to the original size.
5) Convert the Y, C_b, and C_r into the colors R, G, and B.

Note that the JPEG is lossy compression due to the quantization and chroma subsampling.

B. Related Algorithms

We introduce three classical algorithms that are closely related to this study.

The JBF is one of the most common edge-preserving smooth filters with a guidance image. The kernel consists of both of spatial and range kernels. In [5] for color debleeding, the JBF guided with Y is applied to C_b and C_r after the decimalization, dequantization, inverse DCT, and chroma upsampling on the JPEG decoder.[1]

The BM3D [6] is one of the most common and highest-precision algorithms utilizing image self-similarity. It has three steps: 3D transformation of each 3D data array grouped from similar 2D image blocks, shrinkage of the transform spectrum, and inverse 3D transformation.

The GF [7] is one of the most common and fastest edge-preserving smooth filters with a guidance image like the JBF. The kernel is derived from a local linear model.

III. JPEG Decoders With LR and Luma-Guided CRs

This study presents two extended JPEG decoders inspired by the JBF in [5].

[1] Although the reference presented the JBF guided with not only Y but also C_b and C_r, this study omits the trivial extension for simplicity.

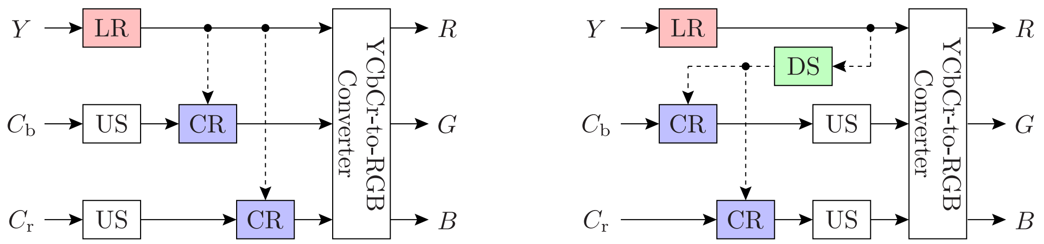

Fig. 1. Flows of the proposed methods (US, DS, and dashed arrow indicate the upsampling, downsampling, and guidance, respectively): (left) the Prop-I and (right) the Prop-II .

A. Extended JPEG Decoder Type-I (Prop-I)

Prop-I has an LR and two luma-guided CRs "after" the chroma upsampling in addition to the standard decoder (see the left of Fig. 1). The Prop-I consists of the following steps:

1) Decimalize the bitstream into the quantized DCT coefficients.
2) Dequantize the quantized DCT coefficients.
3) Convert the coefficients in the spectral domain into one luma Y and two chromas C_b and C_r in the spatial one.
4) [NEW] Restore the Y with an arbitrary LR method.
5) Upsample the C_b and C_r downsampled on the encoder with the default sampling factor $[4:2:0]$ to the original size.
6) [NEW] Restore the C_b and C_r with the GF guided by the restored Y.
7) Convert the Y, C_b, and C_r into the colors R, G, and B.

Note that we can employ arbitrary LR, CR, and upsampling algorithms for the decoder.

B. Extended JPEG Decoder Type-II (Prop-II)

The chroma upsampling before the CR in the Prop-I diffuses the artifacts in C_b and C_r. To suppress the diffusion in the Prop-I, we also introduce Prop-II that has an LR and two luma-guided CRs "before" the chroma upsampling (see the right of Fig. 1). The Prop-II consists of the following steps:

1) Decimalize the bitstream into the quantized DCT coefficients.
2) Dequantize the quantized DCT coefficients.
3) Convert the coefficients in the spectral domain into one luma Y and two chromas C_b and C_r in the spatial one.
4) [NEW] Restore the Y with an arbitrary LR method.
5) [NEW] Downsample the restored Y into the same size as the downsampled C_b and C_r.
6) [NEW] Restore the C_b and C_r with the GF guided by the restored-downsampled Y.
7) Upsample the C_b and C_r downsampled on the encoder with the default sampling factor $[4:2:0]$ to the original size.
8) Convert the Y, C_b, and C_r into the colors R, G, and B.

Like the Prop-I, we can employ arbitrary LR, CR, and upsampling algorithms for the decoder, but note that the downsampling of the luma is required to apply to the downsampled chroma.

TABLE I
PARAMETERS OF THE BM3D AND GF.

BM3D	σ_{psd}	25
	iteration	1
GF	iteration	2
	radius for Prop-I	2
	radius for Prop-II	1
	regularization parameter	0.04

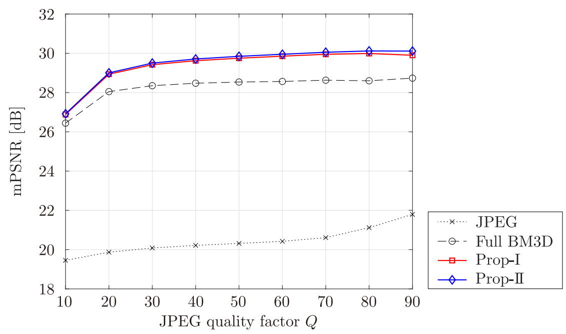

Fig. 2. R-D curves ($Q = 10, 20, \cdots, 90$).

IV. EXPERIMENTS

This study compared the proposed methods with a classical algorithm, full BM3D [6] applied after the whole decoding, at the restoration of the noise-added JPEG-compressed images. For simplicity, we employed the typical classical algorithms such as the BM3D [6], GF [7], and bilinear interpolation for the LR, CR, and chroma upsampling/downsampling, respectively. Table I shows the parameters for the BM3D and GF. We used 24 images of the Kodak Lossless True Color Image Suite [8] as test images and added the AWGN with the standard deviation 0.1 to the images.

Fig. 2 shows the rate-distortion (R-D) curves at mean peak signal-to-noise ratios (mPSNRs) against various JPEG quality factors Q and Fig. 3 shows the actual resulting images. The Prop-II outperformed the full BM3D and Prop-I in almost experiments. Also, the mean execution times for the Prop-I and II were approximately 30-40 % compared to that for the full BM3D because of the very fast implementation of the GF. In addition, the time for Prop-II was slightly shorter than that for the Prop-I because the CR-applied chromas of the Prop-II were smaller than them of the Prop-I. Therefore, it was proved that the proposed decoders can eliminate the

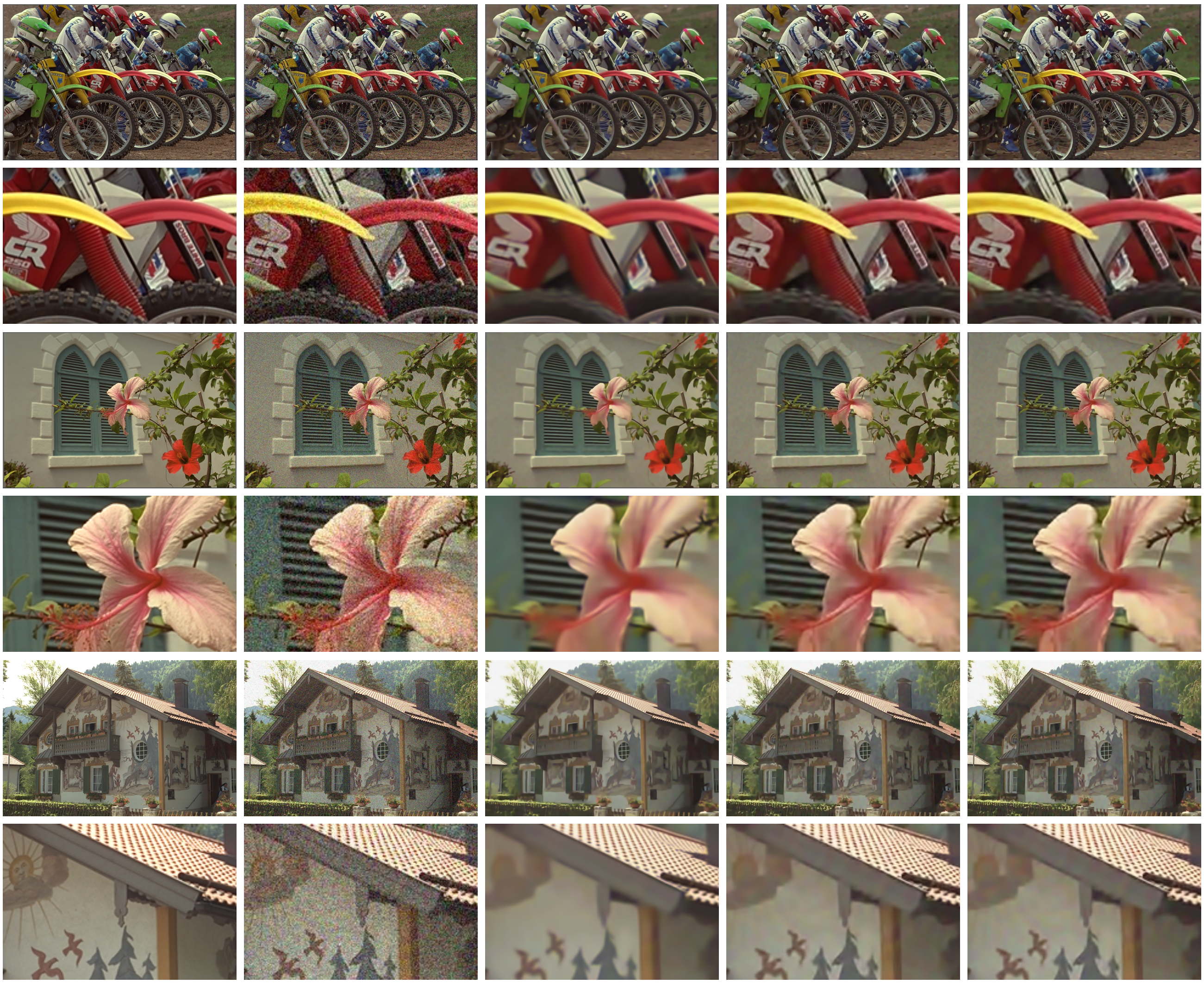

Fig. 3. Resulting images when $Q = 80$: (1st column) original, (2nd column) JPEG compression after noise addition, (3rd column) full BM3D, (4th column) Prop-I, (5th column) Prop-II, (1st/2nd rows) $kodim05$, (3rd/4th rows) $kodim07$, and (5th/6th rows) $kodim24$.

redundant processes and improve the restoration performance.

V. Conclusions

This study presented two extended JPEG decoders that consist of an LR and two luma-guided CRs before/after chroma upsampling in addition to the standard decoder. Only adding new simple algorithms directly to the existing decoder not only eliminated many of the redundant processes, which were required in the conventional methods, but also improved the restoration performance. The experiments showed that the proposed methods restored the noise-added JPEG-compressed images faster and better than the classical one that does not consider the JPEG process.

References

[1] K. Zhang, W. Zuo, S. Gu, and L. Zhang, “Learning deep CNN denoiser prior for image restoration,” in *Proc. CVPR*, Honolulu, HI, July 2017, pp. 3929–3938.

[2] M. Jiu and N. Pustelnik, “A deep primal-dual proximal network for image restoration,” *IEEE J. Select. Topics. Signal Process.*, vol. 15, no. 2, pp. 190–203, Jan. 2021.

[3] P. Liu, H. Zhang, K. Zhang, L. Lin, and W. Zuo, “Multi-level wavelet-CNN for image restoration,” in *Proc. CVPR*, Salt Lake City, UT, June 2018, pp. 773–782.

[4] H. Chen, X. He, C. An, and T. Q. Nguyen, “Deep wide-activated residual network based joint blocking and color bleeding artifacts reduction for 4:2:0 JPEG-compressed images,” *IEEE Trans. Signal Process.*, vol. 26, no. 1, pp. 79–83, Jan. 2019.

[5] N. Wada, M. Kazui, and M. Haseyama, “Extended joint bilateral filter for the reduction of color bleeding in compressed image and video,” *ITE Trans. Media Tech. Appl.*, vol. 3, no. 1, pp. 95–106, Jan. 2015.

[6] K. Dabov, A. Foi, V. Katkovnik, and K. Egiazarian, “Image denoising by sparse 3D transform-domain collaborative filtering,” *IEEE Trans. Image Process.*, vol. 16, no. 8, pp. 2080–2095, Aug. 2007.

[7] K. He, J. Sun, and X. Tang, “Guided image filtering,” *IEEE Trans. Pattern Anal. Mach. Intell.*, vol. 35, no. 6, pp. 1397–1409, June 2013.

[8] “Kodak Lossless True Color Image Suite,” *Kodak [Online]*, Available: http://r0k.us/graphics/kodak/.