Low Bit-rate Subpixel-based Color Image Compression

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The good middle/high rate compression performance and low computational complexity make the JPEG to be an attractive method for natural image compression. Nevertheless, as we go to low bit rates which implies lower quality, JPEG introduces severe disturbing blocking artifacts. Researchers find that at low bit rate, a down-sampled image when compressed and later interpolated, visually beats the high resolution image compressed directly using the same number of bits. A variety of papers have been proposed to improve the performance at low bit rates [1] [2] [3]. There are two problems in previous works: (1) blurring artifacts caused in down-sampling; (2) high complexity when reconstructing the high resolution image. In this paper, we propose a subpixel-based low bit-rate color image compression scheme. The contributions are: (**1**) A decoder-dependent multi-channel subpixel-based down-sampling in the encoder stage is proposed, which is more effective in retaining high frequency details than conventional pixel-based process; (**2**) The compression degradation on the subpixel-based down-sampled image is investigated according to the frequency domain characteristics, which is rarely discussed in the previous literatures; (**3**) A real-time multi-channel subpixel-based reconstruction scheme at the decoder stage is designed by jointly considering the subpixel-based down-sampling effect and the compression degradation in (1) and (2). Fig. 1 presents the dataflow of the proposed method, where $\mathbf{L}$ and $\mathbf{S}_{\text{sp}}$ are original image and subpixel-based down-sampled image at encoder stage. $\mathbf{S}'_{\text{sp}}$ is compressed result of $\mathbf{S}_{\text{sp}}$ and $\mathbf{L}'_{\text{sp}}$ is reconstructed one from $\mathbf{S}'_{\text{sp}}$.

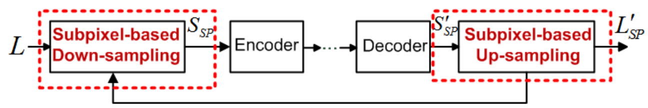


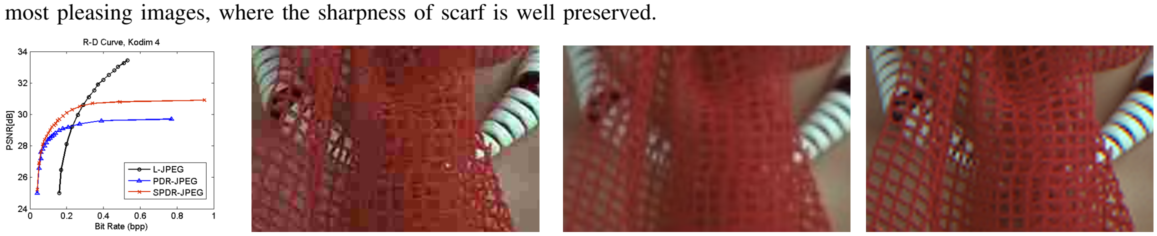
Fig. 1. Block diagram of proposed method.

To find a good subpixel-based down-sampling and up-sampling scheme, we formulate the objective function as

$$\begin{array}{ll} \min & \|\overrightarrow{L} - \overrightarrow{L}'_{\text{sp}}\|_2^2 \\ \text{s.t.} & \overrightarrow{L}'_{\text{sp}} = \mathbf{H}_{\uparrow}\mathbf{H}_o\mathbf{H}_{\downarrow}\overrightarrow{L}, \end{array} \tag{1}$$

where $\mathbf{H}_{\downarrow}$, $\mathbf{H}_o$ and $\mathbf{H}_{\uparrow}$ represent the subpixel-based down-sampling, compression degradation of subpixel-based image, and subpixel-based upsampling respectively. The solution to (1) is $\mathbf{H}^*_{\downarrow} = (\mathbf{H}_{\uparrow}\mathbf{H}_o)^+$, or $\mathbf{H}^*_{\uparrow} = (\mathbf{H}_o\mathbf{H}_{\downarrow})^+$, indicating that the computational complexity could be adaptively concentrated at encoder or decoder by choosing $\mathbf{H}^*_{\downarrow}$ or $\mathbf{H}^*_{\uparrow}$. For example, the users could simply implement subpixel-based "spatial invariant" interpolation at decoder to achieve superior low complexity, while the corresponding subpixel-based down-sampling will be optimized via $\mathbf{H}^*_{\downarrow} = (\mathbf{H}_{\uparrow}\mathbf{H}_o)^+$ at encoder to reduce distortion between input image and reconstructed one, vice versa.

Extensive experiments are carried out to evaluate rate-distortion performance of concerned methods in Fig. 2(a), where black curve represents "L-JPEG" (direct JPEG compression of large image), blue curve is "PDR-JPEG" (JPEG coupled with Pixel-based Down-sampling at the encoder and pixel-based Reconstruction at the decoder), and red curve is the proposed "SPDR-JPEG" (subpixel-based approach). It is obvious that SPDR-JPEG always outperforms PDR-JPEG by providing 1-3dB higher PSNR values. It also provides better performance than "L-JPEG" when bit-rate drops to around 0.3 bpp. Fig. 2(b)-2(d) presents the decoded images at 0.25 bpp. In particular, "L-JPEG" produces blocking artifacts and jaggies. Although "PDR-JPEG" is free of blocking artifacts, it suffers blurring artifacts. "SPDR-JPEG" produces the visually most pleasing images, where the sharpness of scarf is well preserved.



(a) (b) (c) (d)

Fig. 2. Performance comparison for a typical testing image.

In conclusion, compared to existing algorithms with comparable encoder and decoder complexity, the proposed method offers complete standard compliance, competitive rate-distortion performance, and superior subjective quality.

References

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