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Detection method and filters for blocking effect reduction of highly compressed images

Jagroop Singh [a,*], Sukhwinder Singh [b,1], Dilbag Singh [c,2], Moin Uddin [d,3]

[a] *Faculty Department of Electronics & Communication. Engg., DAVIET, Jalandhar 144001, Punjab, India*
[b] *Faculty Department of Computer Science & Engg., UIET, Chandigarh 160014, Punjab, India*
[c] *Faculty Department of Instru. & Control Engg., Dr. B.R.Ambedkar N.I.T, Jalandhar 144001, Punjab, India*
[d] *Dr. B.R. Ambedkar N.I.T, Jalandhar 144001, Punjab, India*

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ABSTRACT

Image compression plays a pivotal role in minimizing the data size and reduction in transmission costs. Many coding techniques have been developed, but the most effective is the JPEG compression. However, the reconstructed images from JPEG compression produce noticeable image degradations near block boundaries called blocking artifacts, particularly in highly compressed images. A method to detect and reduce these artifacts without smoothing images and without removing perceptual features has been presented in this paper. In this work, a low computational deblocking filter with four modes is proposed, including three frequency-related modes (smooth, non-smooth, and intermediate) and a corner mode for the corner of four blocks. Extensive experiments and comparison with other deblocking methods have been conducted on the basis of PSNR, MSSIM, SF, and MOS to justify the effectiveness of the proposed method. The proposed algorithm keeps the computation lower and achieves better detail preservation and artifact removal performance.

1. Introduction

Compression of digital images has gained tremendous importance in telecommunication, video conferencing, videophone, and interactive TV. In fact, given the actual and prospected technologies, data storage and transmission have become important issues. The purpose of the image compression is to reduce the storage and transmission costs while maintaining image quality. The block discrete cosine transform (BDCT) is the most popular transformation technique for image compression such as JPEG [1] for still images, MPEG [2] for moving pictures, and H.261 [3] for videophone/teleconference, because of its compaction property and ease of implementation. However, DCT-based compression methods produce unpleasantly visible degradation at high compression ratios. One of the most noticeable degradations of the block transform coding is the "blocking" artifact. The degradation results because correlation among spatially adjacent blocks is not taken into account in coding. As a result block boundaries become visible when the decoded image is reconstructed. Subjective picture quality can be significantly improved by decreasing the blocking artifacts. Further, if the blocking effects can be significantly reduced, a higher compression ratio can be achieved. Increasing the bandwidth or bit rate to obtain better quality images is often not possible or it is too costly. There is thus, an obvious need of removing blocking artifacts in the low bit-rate transform compressed images.

* Corresponding author. Tel.: +91 98144 44008.
E-mail addresses: roopasidhu@yahoo.com (J. Singh), sukhdalip@yahoo.com (S. Singh), singhd@nitj.ac.in (D. Singh), director@nitj.ac.in (M. Uddin).
[1] Tel.: +91 94177 56421.
[2] Tel.: +91 98884 92132.
[3] Tel.: +91 98881 78786.

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2. Literature survey

Over the past several years, many techniques have been applied to reduce the blocking artifacts in block DCT coded images. Two approaches are generally adopted for the same. In the first approach, the reduction of blocking artifacts is carried out at the encoding side but the methods based on this approach do not conform to the existing standards such as JPEG [1] and MPEG [2]. In the second approach, the reconstructed image is post processed and is aimed to improve its visual quality without any modification in the encoding or decoding mechanisms, making it compatible with JPEG [1] and MPEG [2] coding standards. Because of this advantage, most of the recently proposed algorithms follow the second approach. Post-processing of the decoded image may be carried out in spatial domain or in frequency domain. Iterative methods, based on the theory of projections onto convex sets (POCS), have been proposed in some of the past studies [4–7]. In these methods, initially closed convex constraint sets are defined and these correspond to all of the available data on the original uncoded image. Iterative computations of alternating projections onto these convex sets recover the original image from the coded image. However, these methods usually have high computational complexity, and thus are difficult to adapt to real time image processing applications. Minami and Zakhor gave a new approach for reducing the blocking effect in frequency domain [8]. A new index to measure the blocking effects namely the mean squared difference of slope (MSDS) has been proposed. It is shown that the expected value of the MSDS increases after quantizing the DCT coefficients. This approach removes the blocking effect by minimizing the MSDS, while imposing linear constraints corresponding to quantization bounds. Lakhani and Zhong also reduced blocking effects using MSDS [9]. However, they developed a completely different solution of the optimization problem, leading to the computation of the DCT coefficients that minimizes the MSDS globally. Traintafyllidis et al. have proposed another method of minimizing MSDS, involving diagonal neighboring pixels in addition to horizontal and vertical neighboring pixels [10]. Liu and Bovik proposed a DCT-domain method for blind measurement of blocking artifacts, by modeling the artifacts as 2D step functions in shifted blocks [11]. A fast DCT-domain algorithm extracts all the parameters required to detect the presence of blocking artifacts, using HVS properties. Artifacts are then reduced using an adaptive method. Zeng proposed a simple DCT-domain method for blocking artifact reduction by applying a zero-masking to the DCT coefficients of some shifted image blocks [12]. However, the loss of edge information caused by the zero-masking scheme is noticeable. Luo and Ward [13] and Singh et al. [14] developed techniques that preserved the edge information. These techniques are based on reducing the blocking artifacts in the smooth regions of the image. The correlation between the intensity values of the boundary pixels of two neighboring blocks in the DCT-domain is used to distinguish between smooth and non-smooth regions. However these techniques fail in terms of computational complexity because of several iterations of DCT and IDCT transformations. Chen et al. [15] proposed a filter based on three separate modes for removing blocking artifacts. However, in the intermediate mode, corner pixel values are not selected in the filtering window and hence are not modified. This results in the pixel value that is either much larger or much smaller than the neighboring pixels.

3. Proposed work

An attempt has been made in the present paper to further improve the approach presented in Ref. [15] by adding the concept of corner outlier detection and replacement algorithm with computationally efficient filters for different modes. A corner outlier is visible at the corner point of the 8×8 block, where the corner point is either much larger or much smaller than the neighboring pixels. A low computational deblocking filter with four modes is proposed, including three frequency-related modes (smooth mode, intermediate mode, and non-smooth mode for low-frequency, mid-frequency, and high-frequency regions, respectively) and a corner mode (for the corner of four blocks). In the method proposed in Ref. [15], a 3×3 low pass filter is used in the intermediate mode. In this mode, only the pixels near the block boundary are selected in the filtering window and their gray values are modified within the specified range around the gray values of the neighboring pixels. In the intermediate mode, the corner pixel values are not selected in the filtering window and hence are not modified. This results in the pixel value that is either much larger or much smaller than the neighboring pixels in the corner point of the 8×8 DCT block in the JPEG decompressed image. In addition, a blind but accurate measurement algorithm for blocking artifacts measurement is proposed in this paper. A differentiation between actual edge and artificial discontinuity arising from blocking artifact is made with a view to preserve the actual edges in the image while reducing the artificial discontinuity. For the smooth regions, the reduction of blocking artifact is carried out by modifying four DCT coefficients (two on either side of the block boundary) as compared to six in Ref. [15]. For the non-smooth and intermediate regions, the reduction of blocking artifact is carried out by modifying two DCT coefficients (one on either side of the block boundary) as compared to four in Ref. [15]. After applying filters on the block boundaries, the objective and subjective qualities are both improved as compared to those in Ref. [15] without over-smoothing the image details with less computational complexity.

3.1. Proposed blocking artifact measurement system

Blocking artifacts are introduced in the horizontal and vertical directions. The case of horizontally adjacent blocks namely c_1 and c_2 as shown in Fig. 1 has been studied. The same principles apply for the vertical adjacent blocks as well. Let the right half of c_1 and left half of c_2 form a block denoted as block b. Block b is the 8×8 block that contains the boundary pixels; if any blocking