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Design a deblocking filter with three separate modes in DCT-based coding

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Abstract

The reconstructed images from highly compressed data have noticeable image degradations, such as blocking artifacts near the block boundaries. Post-processing appears to be the most feasible solution because it does not require any existing standards to be changed. Markedly reducing blocking effects can increase compression ratios for a particular image quality or improve the quality of equally compressed images. In this work, a novel deblocking algorithm is proposed based on three filtering modes in terms of the activity across block boundaries. By properly considering the masking effect of the HVS (Human Visual System), an adaptive filtering decision is integrated into the deblocking process. According to three different deblocking modes appropriate for local regions with different characteristics, the perceptual and objective quality are improved without excessive smoothing the image details or insufficiently reducing the strong blocking effect on a flat region. According to the simulation results, the proposed method outperforms other deblocking algorithms in respect to PSNR (Peak Signal-to-Noise Ratio) and SSIM (Structural SIMilarity).

Keywords: Blocking effects; HVS; Deblocking filter; Image compression; Post-processing; DCT; Perceptual quality; Objective quality; PSNR; SSIM

1. Introduction

Image compression is a very problematic issue for many applications in the field of visual communications. The purpose of image compression is to reduce the storage and transmission costs while maintaining image quality. Among the many efficient image compression approaches, block-based transform coding techniques have been widely used in lossy image compression. The block Discrete Cosine Transform (DCT) is the most popular compression transformation and has been developed as a key technique to compress digital image data such as JPEG [1] for still images, MPEG [2] for moving pictures, and H.261 [3] for videophone/teleconference. However, DCT-based compression methods produce unpleasantly visible degradation at high compression ratios. The most noticeable artifact is blockiness, which is due to quantization errors introduced in the encoding process in different blocks of the transformed image. The blockiness is observable as periodical vertical and horizontal false edges, especially in the smoother regions.

2. Existing method for the reduction of blocking effect

Many deblocking approaches have been proposed in still image coding such as JPEG [4–8]. In JPEG, blocking artifacts are assumed to always appear at the block boundaries. The Projection Onto Convex Sets (POCS) by Zakhor [9] is another approach to reducing blocking effects. The key idea is to represent every known property of the original image by a closed convex set. Starting from the block image itself, the solution is an image f that is an element in all sets and can be found by alternation projections onto each set. The quantization constraint defines a set containing all images that would be mapped onto the same blocky image after transforming and quantizing. Let f_{orig} be the

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original image, T be the transformation (e.g., block-DCT), and $Q(\cdot)$ be the quantization. Then, the quantization constraint defines the set of images f for which $\{f|Q(Tf) = Q(Tf_{\text{orig}})\}$. The information that is conveyed by the blocky image data is complemented by a second type of set, which expresses the smoothness along block boundaries. Zakhor uses a set of band-limited images, and the corresponding projection is performed by a low-pass filter. Blocking artifacts are significantly reduced, but some blurring is introduced that cannot be prevented by the quantization constraint. This is mainly because the quantization constraint defines a set that is too large, containing among others, both the original and the blocky image.

The POCS approach by Yang and Galatsanos [10] defines the smoothness set as the set of all images for which the sum of the squared pixel differences across block boundaries is smaller than a specified value. Yang and Galatsanos also propose a Constrained Least Square (CLS) approach in [10]. For the blocky image f_B, the function J_μ is minimized with respect to f as shown in the following equation:

$$J_\mu(f) = \|Sf\|^2 + \mu\|f - f_B\|^2. \tag{1}$$

S is a high-pass operator that measures the blockiness of the image. The first term is small for smooth images, whereas the second term is minimized by the blocky image itself. The parameter μ determines the tradeoff between smoothness and being close to the received blocky image. This tradeoff is similar to that of the POCS approach. The solution is approximated by iteration, and quantization constraint can be incorporated by projecting the solution after each iteration onto the corresponding set of images. The high-pass operator S essentially detects edges, yet cannot distinguish between discontinuities due to blocking artifacts and dominant or texture edges. Thus, texture and dominant edges are not preserved, resulting in slightly blurred images. The operator S has been modified in the CLS algorithm by Jeong et al. [11] to reduce undesired smoothing of edges. An optimal solution is obtained only after waiting for the algorithm to converge to a solution. However, in practical video post-processing application [12,13], the primary concern is to improve the visual quality while maintaining low computational complexity to ensure effectiveness in real-time.

Liu and Bovik [14] proposed a DCT-domain method for blind measurement of blocking artifacts, by modeling the artifacts as 2-step functions in shifted blocks. Zeng [15] proposes a simple DCT-domain method for blocking effect reduction, applying a zero masking to the DCT coefficients of some shifted image blocks. However, the loss of edge information caused by the zero-masking scheme is noticeable. Luo and Ward [16] and Singh et al. [17] gave a new approach which preserved the edge information. These methods 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. Refs. [15–17] lead to huge computation complexity because of several iteration DCT transformation. In this paper, the proposed scheme enhances noisy data by only simple addition and shift operations and is suitable to a real-time environment.

3. Proposed deblocking algorithm

The proposed filter attempts to remove blockiness from an image degraded by quantization noise, by observing the characteristics of each region. This work develops a more effective means of removing blocking artifacts while maintaining an acceptable complexity of computation.

3.1. An overview of proposed the deblocking algorithm

The proposed scheme for alleviating blockiness is based on three separate modes, smooth, intermediate, and complex, that appropriately classify the local characteristics of images according to the above requirements. A mode decision with respect to the observation across a block's boundary is in terms of HVS before a deblocking filter in the three separate modes is applied. The observation will illustrate the characteristics in affected local regions to the blocking effects, clarifying the type of filtering appropriate for each regions. Based on the observation, strong filtering is suggested to be applied to the flat area of block boundary, whereas weak filtering is to be applied to preserve the detail in areas of high spatial or temporal activity. In addition to the two main modes of the deblocking filters, an intermediate mode is designed to solve the problem of a too simplistic decision, and either excessive blurring or inadequate removal of the blocking effect. Finally, the proposed deblocking scheme consists of a decision regarding the mode, and filtering for smooth regions, complex regions, and intermediate region. Figs. 1 and 2 present a detailed flowchart of the proposed deblocking algorithm.

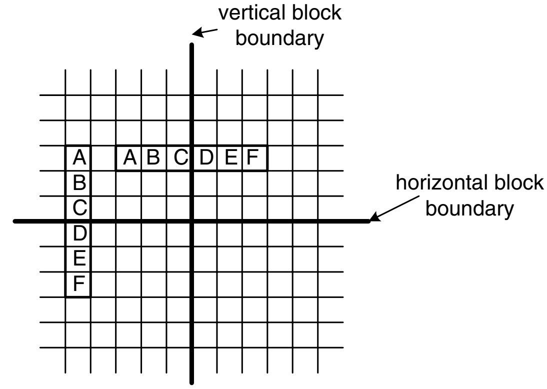

Fig. 1. Position of filtered pixels.