Speeding up DCT-Based Filtering of Images

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Abstract – **This paper addresses an issue of proper parameter selection for a fast DCT-based image filtering in non-overlapping or partially overlapping blocks. Images processed with different parameter sets are compared to each other for a set of test images in terms of standard criteria (output MSE) and visual quality measures (PSNR-HVS-M and MSSIM). Comparison to other fast filters is done as well. Advantages of the proposed methods for fast denoising are demonstrated.**

Keywords - **Filtering of images, fast processing, DCT.**

In many practical situations, images formed by different imaging systems are noisy and, thus, image filtering is a typical operation used for their pre-processing. Numerous filters have been already proposed. Filter choice and its parameter setting depend upon many factors, such as type and characteristics of noise, image properties, set of basic requirements to filtering and their priority.

In our paper, we pay main attention to simplicity and computational efficiency of filters in the first order. Noise suppression and edge/detail preservation as well as visual quality of processed images are also under interest and consideration.

DCT-based filtering can be a good choice for different image processing applications because of several advantages as simplicity, availability of fast implementation, easy adaptation to various types of noise, high efficiency of noise removal and texture preservation.

Processing can be carried out in fully, partly or non-overlapping blocks. In the latter two cases, considerably better computational efficiency is provided. Thus, we pay main attention to these modes of filtering. Besides, filtering efficiency depends upon an algorithm of threshold setting. First, soft, hard and combined thresholds can be exploited. Second, parameter β by which local standard deviation is multiplied also influences filter performance. Third, thresholds can be locally adapted to image content. In the paper, we consider all three possibilities for improving the filter performance.

If full overlapping of blocks is used, optimal β (if it is fixed) is about 2.6 for the case if maximal PSNR (minimal output MSE) are to be provided for the hard threshold mode. If combined threshold is used

$$D_{thr}(m,n,k,l)=\begin{cases} D(m,n,k,l), \text{ if } \left|D(m,n,k,l)\right| \geq \beta\sigma(n,m,k,l) \\ D^3(m,n,k,l)/\beta^2\sigma^2(n,m,k,l) \text{ otherwise} \end{cases},$$

where $D(m,n,k,l)$ is the kl-th DCT coefficient of the mn-th block and $\sigma(n,m,k,l)$ is kl-th aplitude spectrum of noise (spatially correlated in a general case) of the mn-th block, then optimal β is about 4.

The situation changes if one needs to provide the best visual quality of a filtered image with respect to metrics PSNR-HVS-M and MSSIM that take into account peculiarities of human visual system. Then, optimal β is about 2.3 for hard thresholding and about 3.3 for the combined threshold.

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For non-overlapping blocks, it is possible to derive optimal threshold analytically if image component DCT spectrum is known or to adapt it by analyzing parameters of DCT spectrum in each block. However, performance of such DCT filters is considerably (by 2…3 dB) worse than of filters with full overlapping of blocks both in terms of PSNR and PSNR-HVS-M. Besides, blocking artifacts like those ones typical for JPEG-compressed images appear and deteriorate filtered image quality sufficiently.

The use of partly overlapping blocks can be a good trade-off for simultaneous efficient noise suppression without blocking artifacts and high computational efficiency. Such kind of processing is approximately 16 times faster than filtering with full overlapping. Meanwhile, loss of efficiency for filtering with half-block overlapping to full-overlapping processing in terms of PSNR and PSNR-HVS-M can be only about 0.7 dB. Such loss is acceptable in practice and it can be reached if combined threshold is applied. For hard thresholding, the loss is larger. Thus, combined thresholding can be recommended for practice. Its use in combination with half-block overlapping provides better results that for modifications of the sigma filter and can be applied for such application as video sequence filtering.

The conclusions presented above are based on analysis carried out for several standard test images commonly used in experiments: Lenna, Peppers, Barbara, Goldhill, Baboon. The results for the former two images are the most impressive whilst for the image Baboon the gained benefit due to filtering is the smallest. The reason for this is a lot of texture in this image. Although DCT filters are among the best in the sense of texture preservation, noise in textural regions is hardly filters. There are specific textures for which it is not worth applying filtering at all especially if noise variance is quite small.

Results of analysis show that improvement of image visual quality is observed if due to filtering PSNR has increased by about 3 dB (if original PSNR of noisy image was about 30 dB) or by, at least, 6 dB (if original PSNR of noisy image was about 24 dB).

The values PSNR-HVS-M about 40 dB and/or MSSIM about 0.989 correspond to practically invisible distortions both in noisy and filtered images.

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