Post-Processing for Quality Improvement of IDP-Compressed Images

Roumen Kountchev[1] Vladimir Todorov[2] Roumiana Kountcheva[3]

Abstract - **In the paper is offered new approach for the reduction of the blocking artifacts in still images, processed with 2-level Inverse Difference Pyramid (IDP) decomposition, based on Walsh-Hadamard and DCT orthogonal transforms. For this purpose was developed a two-dimensional fuzzy digital filter, whose performance changes in accordance with the image contents, framed by the filter window, and depending on the compression ratio and the maximum approximation error, obtained in the second (higher) IDP level. The experimental results show, that the block artifacts in the restored images are reduced without visual deterioration of the image sharpness. The advantages of the new filter are its low computational complexity and adaptation abilities. In the paper are analyzed the abilities for the filter implementation aiming at the quality improvement of decompressed color images with blocking artifacts.**

Keywords – **Deblocking filter, Two-dimensional Adaptive Fuzzy Filter (2DAFF), Image Compression, Inverse Difference Pyramid (IDP), Discrete Cosine Transform (DCT).**

I. INTRODUCTION

The block-transformed techniques for image coding, based on orthogonal transforms, usually generate significant distortions, called blocking artifacts [5,16] and this effect is accentuated at high compression ratios. These artifacts display themselves as artificial boundaries between adjacent blocks or around sharp transitions in the processed images. The distortions of the second kind, called ringing artifacts, are a result of the Gibbs effect and are due to the quantization of the used transform coefficients. In order to minimize the artifacts in the decompressed images are already developed significant number of methods for pre- and post – processing [2-13]. The methods in the second group could be classified as follows: Direct linear or non-linear smoothing techniques in the spatial domain [7-10]; Combined techniques employing both edge detection or segmentation for detail classification and spatial adaptive filtering [11]; Iterative techniques based on the theory of projections on to convex set (POCS) [6,12], and Soft threshold approaches in the wavelet domain [13]. The major issues existing in the current post-processing methods can be summarized in brief as: limitation to a certain type of artifacts, concerning the methods in the first group, mentioned above, and such with high computational complexity – included in the remaining three groups.

[1] Roumen Kountchev is with the FCTT, Radiocomunications Dept., Technical University of Sofia, Bul. Kl. Ohridsky 8, Sofia, Bulgaria, E-mail: rkountch@tu-sofia.bg

[2,3] Vladimir Todorov and Roumiana Kountcheva are with T&K Engineering, Mladost 3, P.O.Box 12, Sofia 1712, Bulgaria
E-mails: todorov_vl@yahoo.com. kountcheva_r@yahoo.com

In the paper is offered a relatively simple and efficient technique for removing various blocking artifacts using a two-dimensional fuzzy digital filter, which is quite adequate for the processing of decompressed images, obtained using IDP decomposition, based on DCT and Walsh-Hadamard transforms. In Section II is presented the algorithm for fuzzy filtration, in Section III is described the approach, used for the adaptation of the offered filter, in Section IV are presented the results of the modeling of the filter performance for test images compressed using the IDP decomposition and in the Conclusion are pointed the advantages of the new filter and its possible applications.

II. POST-PROCESSING WITH FUZZY ADAPTIVE FILTER

The offered approach for post-processing of decompressed images is based on the use of fuzzy digital filters [1,3], which became very popular recently. The algorithm for the performance of the two-dimensional fuzzy adaptive filter (2DFAF), using a sliding window with size MxN pixels (M=2R+1 and N=2S+1), is as follows:

$$x_F(i,j)=\begin{cases}\left\lfloor \dfrac{\sum_{r=-R}^{R}\sum_{s=-S}^{S}\mu(i+r,j+s)\,x(i+r,j+s)}{\sum_{r=-R}^{R}\sum_{s=-S}^{S}\mu(i+r,j+s)} \right\rfloor & \text{for } \sum_{r=-R}^{R}\sum_{s=-S}^{S}\mu(i+r,j+s)\geq T,\\[2ex] \left\lfloor (1/MN)\sum_{r=-R}^{R}\sum_{s=-S}^{S}x(i+r,j+s) \right\rfloor & \text{- in all other cases,}\end{cases} \tag{1}$$

where $\lfloor \circ \rfloor$ is a rounding operator; T – a noise threshold $x(i,j)$ and $x_F(i,j)$ are correspondingly the pixels of the input and of the filtered output image;

$$\mu[\Delta(i+r,j+s)]=\begin{cases}1 & \text{for } \Delta(i+r,j+s)\leq\alpha;\\ \dfrac{\Delta(i+r,j+s)-\alpha}{\alpha-\beta} & \text{for } \alpha\leq\Delta(i+r,j+s)\leq\beta;\\ 0 & \text{for } \Delta(i+r,j+s)\geq\beta,\end{cases} \tag{2}$$

Here Eq. 2 represents the chosen membership function with parameters α and β (β > α), whose argument Δ is the module of the difference between the central pixel x(i,j) in the filter window and the pixel x(i+r, j+s), moved at the distance (r, s):

$$\Delta(i+r,j+s)=\left|\,x(i,j)-x(i+r,j+s)\,\right| \tag{3}$$

for $r=\overline{-R,+R}$ and $s=\overline{-S,+S}$.

The values of parameters α and β are defined in accordance with the image contents and with the kind of the distortions, which should be corrected or suppressed. In the case, when block artifacts obtained in result of the high image compression are concerned, α and β are defined in depending on the compression ratio and the kind of the used compression algorithm. In the presented approach the 2DFAF filter is applied on images with block artifacts obtained in result of lossy compression based on Inverse Difference Pyramid (IDP) decomposition [14] with high compression ratio.

III. Adaptation of the 2DFAF filter

For the suppression of the block artifacts in images obtained in result of the IDP compression parameters α and β of the 2DFAF filter are defined in accordance with the relations:

$$\alpha = \delta - \varepsilon, \quad \beta = \delta + \varepsilon, \tag{4}$$

where δ identifies the center of the filter fuzziness, for which the function $\mu(\Delta) = 0.5$, and ε defines the boundaries of the deviation δ. The value of the parameter δ is defined following the condition:

$$\delta = \frac{1}{2}\left| \hat{E}_0(i,j)_{max} \right| . \tag{5}$$

Here $E_0(i,j)_{max}$ is a pixel of the matrix $[E_0]$ containing the error between the original image and its approximation in the second IDP level. The parameters ε and T of the 2DFAF filter are chosen experimentally in accordance with the compression ratio and the noise level.

IV. Experimental results

The experiments were performed with parameters ε = 1 and T=2. The research on the new filter was performed with the software, implementing the algorithm. The filter treats the brightness component of the image only. For the investigation were used large number (more than 100) grayscale and color images. In the investigation was used the 100-stage quality factor (QF) set used for the IDP decomposition, defined by a number of parameters (QF1 is for the best quality and the smallest compression, QF100 – correspondingly for the worst quality and the highest compression ratio). The set of parameters used for the definition of the QF stages comprises the number of pyramid levels, the approximation transform (DCT or WHT) used in the pyramid levels, the quantization values, the used transform coefficients, the scanning arrangement of the values, calculated for same spatial frequencies coefficients, etc.

Some of the obtained results are presented below. In Fig. 1 are given the mentioned test images "Lena", "Peppers" and "Fruits". In Fig. 2 are presented the results obtained for same test images after compression with quality factors QF: 40,50 and 70 and treating the images with filter, whose window is with size 3x5 pixels and whose center of fuzziness changes from 5 to 65. The vertical axis shows the change of the image quality measured as PSNR. One unit in the vertical axis is 0,01 dB.

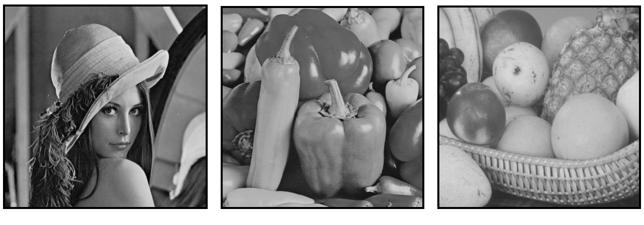


Fig. 1. Test images: "Lena", "Peppers", "Fruits"(originals)

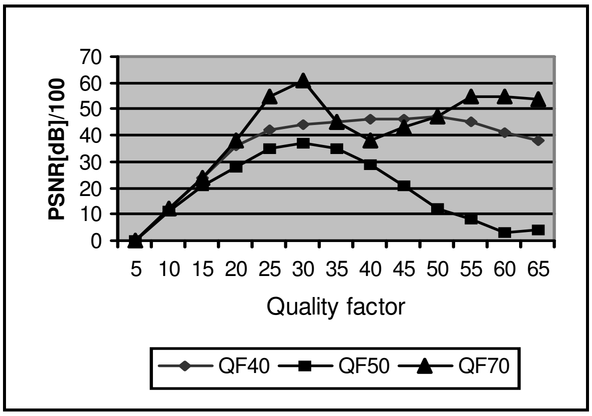


Figure 2a. "Peppers".

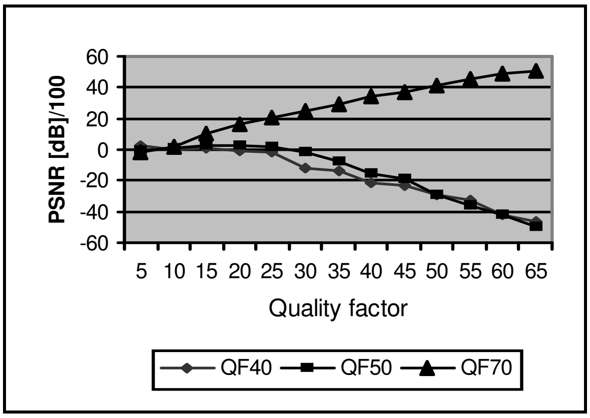


Figure 2b. "Lena"

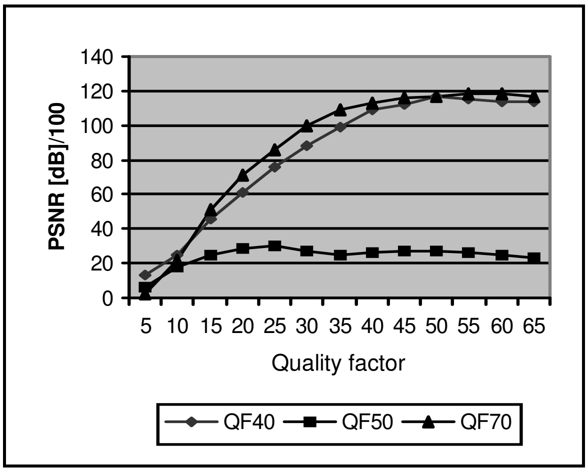


Figure 2. c. "Fruits"

The results show that the results are best for images restored after high IDP compression (corresponding with QF70 for these examples). Together with the increasing of the QF the filter influence increases as well.

In Fig, 3 are presented the results obtained for the test image "Lena" changing the quality factor from 50 to 100 and treating the restored image with filter window with width 3 and 5 pixels (the window height is 5 pixels in both cases). The results obtained for the other test images are similar. Best results are obtained for filter with window width 3 pixels. The vertical axis (for which one unit is equal to 0,01 dB) represents the image quality change.

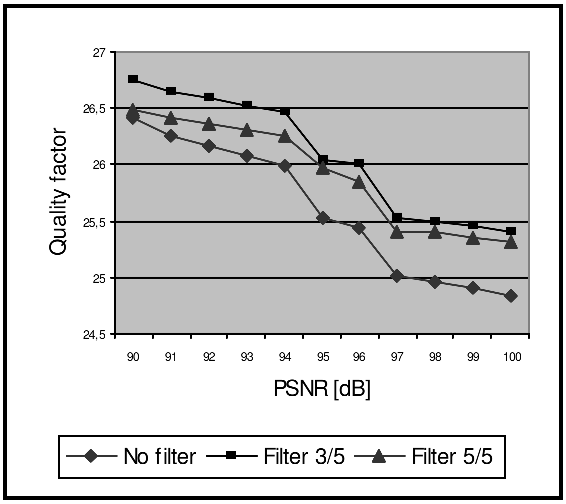


Fig. 3. Influence of the window filter width change (Image "Lena")

These results are in correspondence with the IDP decomposition approach and they suit the size of the sub-image in the higher pyramid level very well (as it was already mentioned, the sub-images in the upper pyramid level are with size 4x4 pixels).

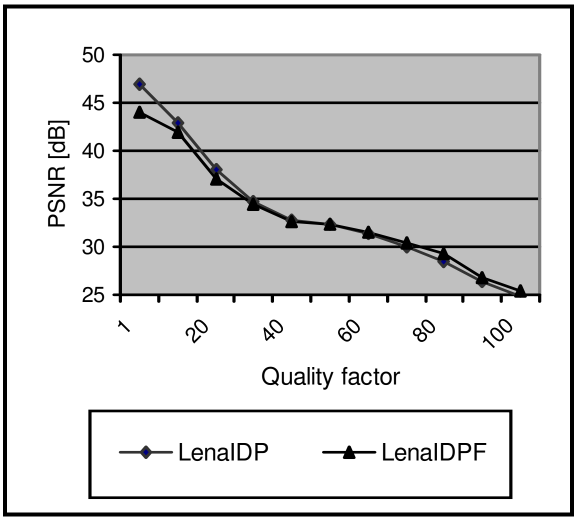


Fig. 4. Image Lena, IDP coding

In Figure 4 are presented the results obtained for the filter performance for the full 100-stage IDP quality factor range. The horizontal axis represents the QF and the vertical – the restored image quality (one unit corresponds to 0,01 dB). The results show that for low QF (i.e. low compression ratio), when the PSNR of the restored image is high (above 45 dB) the filter decreases the image quality. Its performance is useful for QF higher than 50, i.e. when the restored image quality is less than 30 dB.

In Fig. 5 is presented the result of the filtration for part of the image "Pepper" after IDP compression with QF = 86 (Compression ratio = 35). The visual quality improvement is noticeable. Similar results were obtained for the remaining test images. General result for all tested images is that for QF over 90, where the image quality is significantly decreased, better visual results are obtained with filter with window width 7 pixels. The PSNR of the filtered image is lower for window width 7, but the visual quality is much better. These results correspond with the IDP decomposition, because for these QF values the image sub-blocks are with size 8x8 pixels.

Fig. 5a. Decompressed image "Peppers" (QF86, CR=35)

Fig. 5b. The same decompressed image after filtration

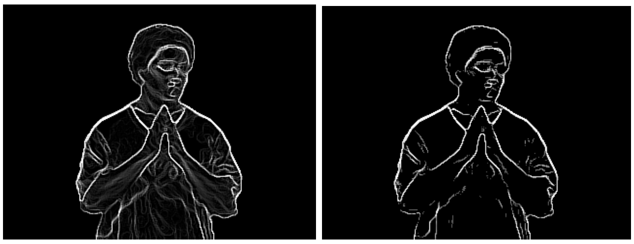
In Fig. 6a,b is presented the decompressed image "Lena" after IDP compression with QF 100 and the same image after filtration.

a b

Fig. 6. Test image "Lena" restored after compression with QF100 and filtration with filter, which center of fuzziness is 65 and the filter window width is 7 (the filter height is 5).

The general result from the performed investigation is that the IDP compression method gives enough information for setting the values of the filter parameters in the process of the image coding. As it was already pointed, the main parameters are its center of fuzziness and the window width. Best results are obtained when the filter center of fuzziness is set to be equal to the half of the maximum difference calculated between the original and the restored image in the coding side. The experiments proved that the filter window width should be 3 for all QF in the range of 50 to 90 and 7 for the range of 90 to 100.

The filter gives very good results for treatment of multi-level contour images, in particular - their adaptive segmentation retaining maximum visual similarity with the original. In result of the filtration the contours extraction is easier and the compression - more efficient. The detailed presentation of the research results on contour images will be presented in another work.



a b

Fig. 7a. Contour image (contours were extracted with Corel Photo Paint 10, Edge detection); b. Same image, after filtration.

Example of the obtained results is presented in Fig. 7. In Fig. 7a is presented the original contour image, and the filtered image is presented in Fig. 7b. It is easy to notice that the number of contours in the filtered image is smaller, retaining the most important details.

V. Conclusion

The experimental results proved the efficiency of the proposed approach. In result of the performed research work are defined the following conclusions:

- The two-dimensional adaptive digital filter improves the quality of decompressed images, compressed to high degree with IDP compression;
- The filter parameters suit very well the IDP decomposition, because there is a definite relation between them and the IDP quality factor;
- The filter parameters are defined in the process of the image compression and the corresponding data is included in the obtained compressed data file. This additional information is negligible, because the filter needs two parameters only: the center of fuzziness and the filter window width, i.e. two bytes only.
- The filter improves the quality of the decompressed image in the whole range from QF 50 to QF 100.
- The mean quality improvement for the tested images is 0,4dB, but the visual quality improvement is very good.
- The filter has low computational complexity and its implementation in software solutions based on the IDP image decomposition does not slow-down their performance.

VI. Acknowledgement

This paper was supported by NSF of Bulgarian Ministry of Education and Science (Contract ВУ-МИ-104).

References

[1] M. Nachtegael et all. “Fuzzy Filters for Image Processing”, Springer-Verlag, 2003.

[2] Ch. Tu, T. Tran, J. Liang, “Error Resilient Pre-/Post Filtering for DCT-Based Block Coding Systems”, Proc. of the 2003 IEEE Intern. Conf. on Acoustics, Speech, and Signal Processing, Hong Kong, Vol. III, pp. 153-156, April 2003.

[3] Y. Nie, K. Barner, “Optimized Fuzzy Transformation for Image Deblocking”, IEEE ICME, Vol. I, pp. 541-544, March 2003.

[4] S. Minami, A. Zakhor, “An optimization approach for removing blocking effects in transform coding,” IEEE Trans. on Circuit and System for Video Technology (CSVT), Vol. 5, No. 2, pp. 74–82, Apr. 1995.

[5] T. Meier, K. Ngan, G. Crebbin, “Reduction of coding artifacts at low bit rates”, Proc. SPIE Visual Communications and Image Processing, San Jose, January 1998.

[6] Y. Yang, N. Galatsanos, “Removal of compression artifacts using projections onto convex sets and line modeling”, IEEE Trans. on Image Processing, 6, October 1997.

[7] Y. Yang, N. Galatsanos, A. Katsaggelos, “Projection-Based Spatially-Adaptive Reconstruction of Block Transform Compressed Images", IEEE Trans. on Image Processing, Vol. 4, No. 7, pp. 896-908, July 1995.

[8] S. Kim, J. Yi, H. Kim, J. Ra, “A Deblocking Filter with Two Separate Modes in Block-Based Video Coding,” IEEE Trans. CSVT, Vol. 9, No. 1, Feb. 1999.

[9] J. Chou, M. Crouse, K. Ramchandran, “A Simple Algorithm for Removing Blocking Artifacts in Block-Transform Coded Images,” IEEE Signal Processing Letters, Vol. 5, No. 2, Feb. 1998.

[10] S. Masri, R. Castangno, G. Ramponi, “A Simple Algorithm for the Reduction of Blocking Artifacts in Images and its Implementations”, IEEE Trans. on Consumer Electronics, 44, August, 1998.

[11] A. Al-Fahoum, A. Reza, “Combined Edge Crispiness and Statistical Differencing for Deblocking JPEG compressed Images”, IEEE Trans. on Image Processing, Vol. 10, No. 9, Sept. 2001, pp. 1288-1298.

[12] R. Rosenholtz, A. Zakhor, “Iterative Procedure for Reduction of Blocking Effects in Transform Image Coding”, IEEE Trans. CSVT, Vol. 2, Mar. 1992, pp. 91-95.

[13] S. Wu, H. Yan, Z. Tan, “An Efficient Wavelet-Based Deblocking Algorithm for Highly Compressed Images,” IEEE Trans. CSVT, Vol. 11, No. 11, Nov. 2001, pp. 1193-1198.

[14] R. Kountchev, M. Milanova, C. Ford, R. Kountcheva. “Multilayer Image Transmission with Inverse Pyramidal Decomposition”. In “Computational Intelligence for Modeling and Predictions”, S. Halgamuge, L. Wang (Eds.), Vol. 2, Springer-Verlag, pp. 179-196, 2005.

[15] R. Kountchev, M. Milanova, C. Ford, S. Rubin, R Kountcheva. Lossless image compression with IDP and Adaptive RLC. Proc. of Intern. Conf. on Imaging Science, Systems and Technology (ISST’04), Las Vegas, USA, June 2004,pp. 608-612.

[16] I. Richardson, “H.264 and MPEG-4 Video Compression - Video Coding for Next-generation Multimedia”, John Wiley & Sons Ltd, 2003.