

CORRECTION OF QUANTIZATION ERRORS IN COMPRESSED COLOR IMAGES

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Abstract: A method for the reduction of quantization errors in compressed multichannel RGB images is presented. The proposed method adopts fuzzy relations among neighboring pixels in order to reconstruct the data corrupted during the coding process. Results of computer simulations show that the method is simple and effective. Unlike other techniques in the literature, no complicated tuning of the parameters is necessary. Blocking and ringing artifacts are effectively reduced and the quality of the image is satisfactorily preserved.

Keywords: measurement of electrical quantities, quantization, noise cancellation

1 INTRODUCTION

Digital images are subject to quantization processes that typically occur during acquisition, digital conversion, color interpolation and lossy compression. In particular, with the continued growth of multimedia and communication systems, images subjected to lossy compression (such as the JPEG method) have become very popular [1-2]. Indeed, image compression represents a very attractive solution when digital recording and/or transmission of large amounts of data are a very critical issue. Common approaches to image compression resort to transform-based methods. In order to obtain high compression ratios, these approaches usually perform quantization of transform coefficients during the encoding process. However, since a part of the information is lost, the decoding unit cannot exactly reproduce the original data and the resulting image is then affected by errors. The most annoying effects typically include *blocking* and *ringing* artifacts [3]. Blocking artifacts are generated by independent coding of adjacent groups of pixels and are clearly perceivable as abrupt transitions of luminance across block boundaries. Ringing artifacts are typically represented by sharp oscillations or "ghost shadows" located along the edges of the image. Different post-processing techniques have been proposed in the literature in order to reduce these effects [4-7].

In this paper a method for the correction of quantization errors in compressed color images is presented. The proposed method adopts fuzzy models and extends our previous approach to the case of multichannel image data [8]. The method is simple and effective. Unlike other techniques, it does not require complicated tuning of parameters. In fact, the method operates on the R, G and B channels independently. For each channel, only one parameter is necessary to adjust the error-correction behavior. As a result, a satisfactory reduction of blocking and ringing artifacts can easily be obtained. This paper is organized as follows. Sect.2 describes the proposed method, Sect.3 analyzes the experimental results and, finally, Sect.4 reports conclusions.

2 THE PROPOSED METHOD

Let us suppose we deal with digitized multichannel RGB images. The value at each image pixel is taken to be a 3-D vector. Let $\mathbf{x}(i,j)$ be the vector at location (i,j) : $\mathbf{x}(i,j) = (x_1(i,j), x_2(i,j), x_3(i,j))^T$, where $0 \leq x_k \leq Q$ ($k=1,2,3$). The method is based on a fuzzy filter that operates on a 3×3 window. The output $\mathbf{y}(i,j) = (y_1(i,j), y_2(i,j), y_3(i,j))^T$ is given by the following relationship:

$$y_k(i,j) = x_k(i,j) + \frac{a_k}{8} \left[\sum_{m=-1}^1 \sum_{n=-1}^1 \alpha_k(i,j,m,n) - \sum_{m=-1}^1 \sum_{n=-1}^1 \beta_k(i,j,m,n) \right] \quad (1)$$

where:

$$\alpha_k(i,j,m,n) = \mu_k[x_k(i+m,j+n), x_k(i,j)] \quad (m,n) \neq (0,0) \quad (2)$$

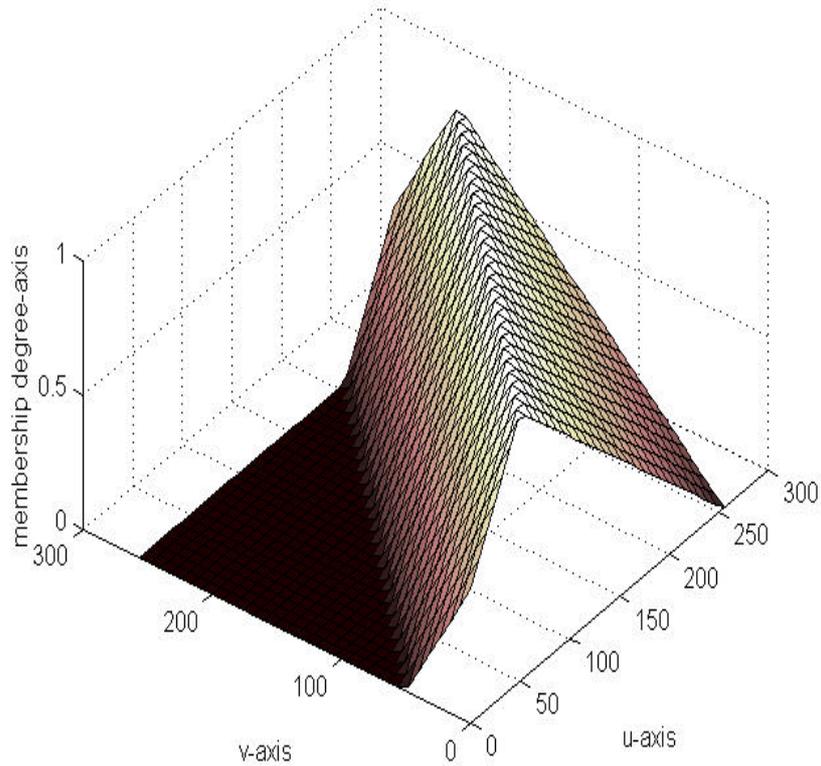


Figure1. Graphical representation of the membership function $\mu_k(u,v)$.

$$\beta_k(i, j, m, n) = \mu_k[x_k(i, j), x_k(i + m, j + n)], \quad (m, n) \neq (0, 0) \quad (3)$$

$$\alpha_k(i, j, 0, 0) = \beta_k(i, j, 0, 0) = 0 \quad (4)$$

and $\mu_k(u, v)$ ($k=1, 2, 3$) is the parameterized membership function of the fuzzy relation “ u is a bit greater than v ”. This membership function is formally defined as follows:

$$\mu_k(u, v) = \begin{cases} 1 - \frac{u - v - a_k}{Q - a_k} & a_k \leq u - v \leq Q \\ \frac{1}{2} + \frac{u - v}{2a_k} & -a_k \leq u - v < a_k \\ 0 & -Q \leq u - v < -a_k \end{cases} \quad (5)$$

A graphical representation of μ_k is shown in Fig. 1 ($a_k=50$). The particular 2-D shape of this function is based on our previous research work [9]. By varying the parameter a_k , the smoothing behavior of the fuzzy filter can easily be controlled in order to reduce quantization noise and preserve image details, as well.



Figure 2. "Lena" compressed at about 20:1.



Figure 3. Result yielded by the proposed method.

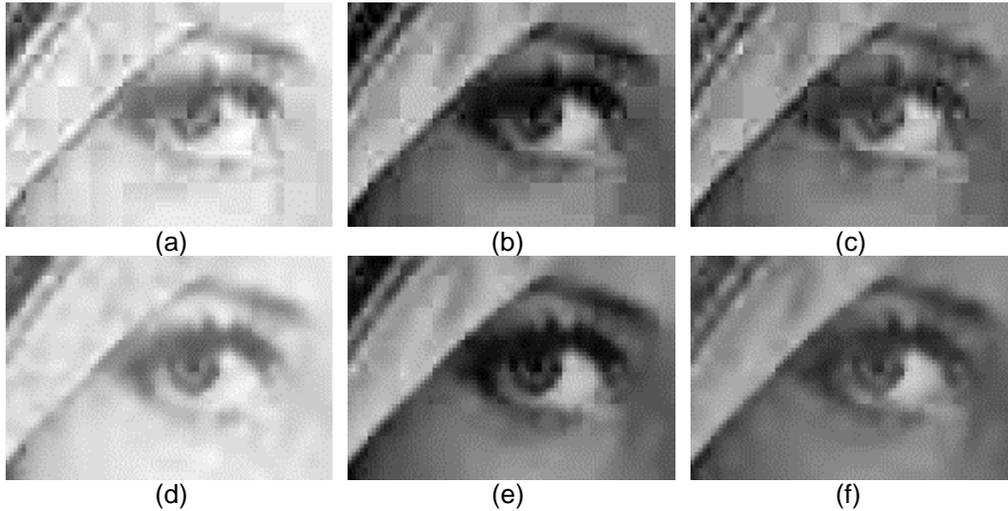


Figure 4. Detail of the “Lena” image: RGB components of the compressed data (a), (b) (c), and of the filtered data (d), (e) (f).

3 EXPERIMENTAL RESULTS AND PERFORMANCE ANALYSIS

In order to assess the performance of the proposed method, an application example is here discussed. In this experiment, we have considered a 256×256 slice of the well known 512×512 "Lena" picture ($Q=255$). The image compressed at about 20:1 by means of the JPEG technique is shown in Fig. 2. The result of the application of the proposed method is depicted in Fig. 3. We can observe that both blocking and ringing artifacts have been significantly reduced. In order to analyze the filtering behavior, a detail of the image is also shown in Fig. 4. The RGB components of the compressed data are reported in Fig. 4a, 4b and 4c. The corresponding filtered components are depicted in Fig. 4d, 4e and 4f, respectively. The ability to correct quantization errors is apparent. As an example, look at the R component represented in Fig. 4a. Lena's eye is severely disrupted by blocking artifacts caused by quantization and the resulting effect is very annoying. However, the eye is perfectly reconstructed after fuzzy filtering (Fig. 4d). No block is now perceivable and the shape of the eye is circular, as it should be. In order to obtain a measure of the performance of the fuzzy technique we have also estimated the mean square error (MSE) between the processed and the original RGB components.

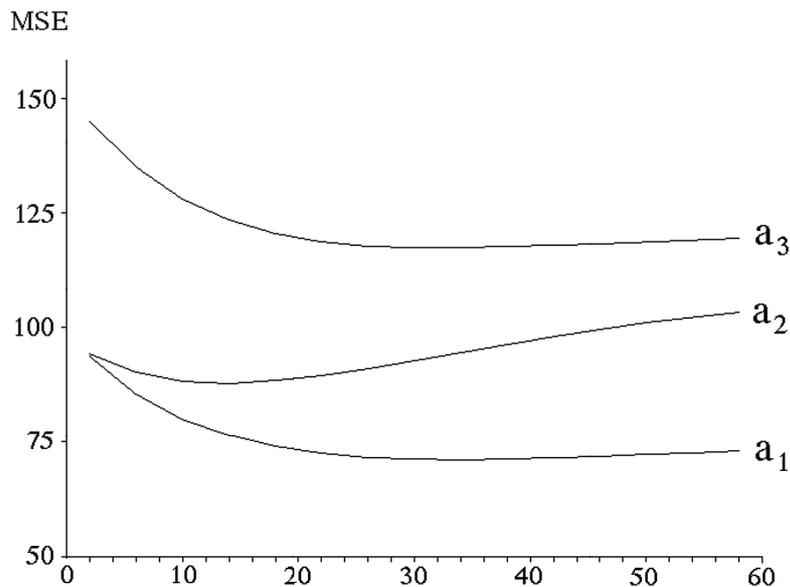


Figure 5. MSE values for the RGB components.

The error correction behavior is graphically represented in Fig. 5. It should be observed that high compression ratios tend to cancel very fine details during the encoding process. Hence the parameter tuning is not a very critical task. Indeed, we can easily find a satisfactory set of parameter values that can effectively reduce coding errors without any further loss in image information.

4 CONCLUSIONS

A new method for the correction of quantization errors in compressed color images has been presented. The proposed method is based on a fuzzy filter that gradually adapts the smoothing behavior in order to preserve the image information during error correction. The approach is simple and effective. The fuzzy filtering operates on the R, G and B channels independently and, for each channel, only one parameter is necessary to adjust the error correction behavior. Experimental results have shown that blocking and ringing artifacts can be effectively removed from the data without any further loss in image information.

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REFERENCES

- [1] ISO-IEC CD 10918-1, *Digital Compression and Coding of Continuous-tone Still Images, Part 1: Requirements and Guidelines*, March 15, 1991.
- [2] W. B. Pennebaker and J. L. Mitchell, *JPEG Still Image Data Compression Standard*, Van Nostrand Reinhold, 1993.
- [3] Y. Yang and N. P. Galatsanos, "Removal of Compression Artifacts Using Projections onto Convex Sets and Line Process Modeling", *IEEE Trans. on Image Processing*, vol.6, n.10, October 1997, pp.1345-1357.
- [4] K. I. Diamantaras and M. G. Strinzis, "Optimal Transform Coding in the Presence of Quantization Noise", *IEEE Trans. on Image Processing*, vol.8, n.11, November 1999, pp.1508-1515.
- [5] C. Kuo and R. Hsieh, "Adaptive Postprocessor for Block Encoded Images", *IEEE Trans. Circuits Syst. Video Technol.*, vol.5, August 1995, pp.298-304.
- [6] J. Luo, C. Chen, K. Parker and T. S. Huang, "Artifact Reduction in Low Bit Rate DCT-Based Image Compression", *IEEE Trans. on Image Processing*, vol.5, n.10, September 1996, pp.1363-1368.
- [7] R. Castagno and G. Ramponi, "A Rational Filter for the Removal of Blocking Artifacts in Image Sequences Coded at Low Bitrate", in Proc. European Signal Processing Conference, EUSIPCO-96, Trieste, Italy, September 10-13, 1996, pp.567-570.
- [8] F. Russo, "A Fuzzy Approach to Quality Enhancement of Images Degraded by Coding", in Proc. IEEE International Workshop on Emerging Technologies, Intelligent Measurements and Virtual Systems for Instrumentation and Measurements, ETIMVIS/98, St. Paul, Minnesota, USA, May 15-16, 1998.
- [9] F. Russo, "Noise Removal from Image Data Using Recursive Neuro-Fuzzy Filters", *IEEE Transactions on Instrumentation and Measurement*, vol. 49, n.2, April 2000.

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