

# AUTOMATIC REDUCTION OF NOISE IN DATA ACQUIRED BY DIGITAL CAMERAS

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**Abstract** - A technique for automatic noise correction in color images acquired by digital cameras is presented. The proposed method deals with the R, G and B components of the image and adopts a nonlinear approach in order to perform a very accurate restoration of the data. The optimal parameters that define the key filtering action are obtained by an automatic procedure that independently operates on each channel. Experimental results show that the method is very effective and well suited to correct the typical noise increase that occurs when high sensitivity is chosen during image acquisition.

**Keywords** – Noise cancellation, digital cameras, image processing.

## 1. INTRODUCTION

It is well known that the presence of noise can significantly reduce the accuracy of any imaging system. For this reason, the adoption of post-processing techniques that can restore the corrupted data plays a very relevant role. Nowadays digital cameras are finding widespread diffusion due to the availability of low cost and high resolution image sensors. Most advanced features often include the selection of the sensitivity that can typically range from ISO 100 to ISO 800 equivalent and more. Such a feature is of paramount importance when the flash unit cannot be used and the shutter speed should be sufficiently high in order to avoid possible motion artifacts of the subject. However, the noise can significantly increase and its effect on the acquired data can result very annoying, especially in the low-luminance areas of the image.

In order to address this issue, a new method for automatic noise correction in color images is presented. The proposed approach is based on our previous research work and adopts a new nonlinear filtering mechanism that can gradually adapt the smoothing action in order to better combine noise smoothing and preservation of the image details. Unlike existing techniques [1-4] that usually require some “a priori” knowledge about the noise statistics, the proposed

method can automatically find the main parameter settings that yield a very accurate restoration of the color image data. This paper is organized as follows. Sect.2 describes the new adaptive algorithm, Sect.3 focuses on parameter settings, Sect.4 presents a technique for improving the noise cancellation, Sect.5 discusses some experimental results and, finally, Sect.6 reports conclusions.

## 2. THE NEW ADAPTIVE ALGORITHM

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  $\mathbf{x}(\mathbf{n})$  be the vector at location  $\mathbf{n}=[n_1, n_2]$  in the noisy image:  $\mathbf{x}(\mathbf{n}) = (x^{(1)}(\mathbf{n}), x^{(2)}(\mathbf{n}), x^{(3)}(\mathbf{n}))^T$ , where  $0 \leq x^{(k)} \leq L$  ( $k=1,2,3$ ) and typically  $L=256$  for a 24-bit color image. For the sake of simplicity, let  $x_1^{(k)}(\mathbf{n}), x_2^{(k)}(\mathbf{n}), \dots, x_N^{(k)}(\mathbf{n})$  briefly denote the set of  $N=8$  neighboring pixels that belong to a  $3 \times 3$  window around  $x^{(k)}(\mathbf{n})$  in the  $k$ -th channel, as shown in Fig.1.

$x_2^{(k)}(\mathbf{n})$	$x_3^{(k)}(\mathbf{n})$	$x_4^{(k)}(\mathbf{n})$
$x_1^{(k)}(\mathbf{n})$	$x^{(k)}(\mathbf{n})$	$x_5^{(k)}(\mathbf{n})$
$x_8^{(k)}(\mathbf{n})$	$x_7^{(k)}(\mathbf{n})$	$x_6^{(k)}(\mathbf{n})$

Fig.1 -  $3 \times 3$  window.

The output  $\mathbf{y}(\mathbf{n}) = (y^{(1)}(\mathbf{n}), y^{(2)}(\mathbf{n}), y^{(3)}(\mathbf{n}))^T$  of the new filter is given by the following relationship:

$$y^{(k)}(\mathbf{n}) = x^{(k)}(\mathbf{n}) + \frac{1}{N} \sum_{i=1}^N \beta_k(x_i^{(k)}(\mathbf{n}), x^{(k)}(\mathbf{n})) \quad (1)$$

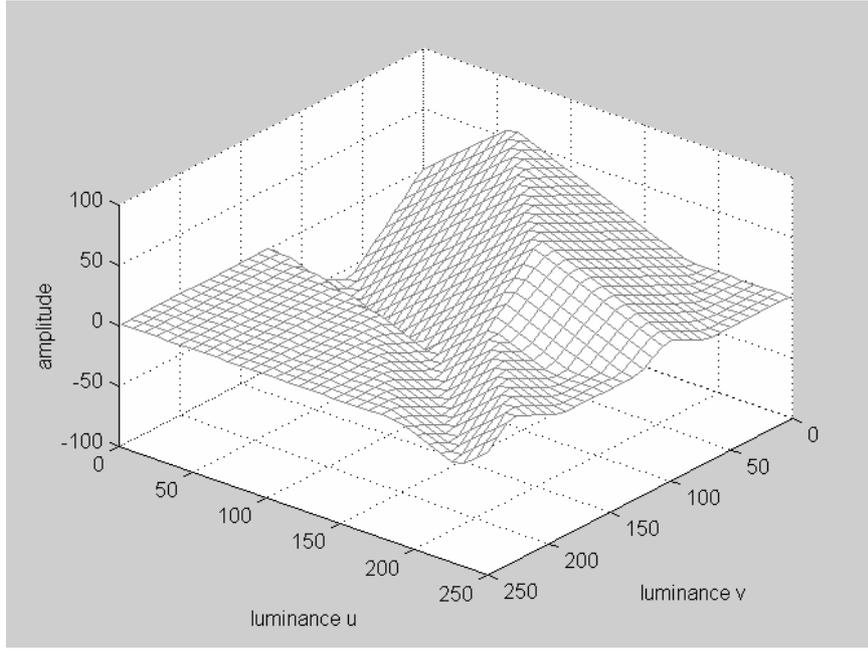


Fig.2 - Example of graphical representation of  $\beta_k(u, v)$ .

where  $\beta_k$  is a nonlinear function:

$$\beta_k(u, v) = \begin{cases} 0 & u - v > 3\alpha_k \\ \frac{3\alpha_k - u + v}{2} & \alpha_k < u - v \leq 3\alpha_k \\ u - v & -\alpha_k < u - v \leq \alpha_k \\ -\frac{3\alpha_k + u - v}{2} & -3\alpha_k < u - v \leq -\alpha_k \\ 0 & u - v \leq -3\alpha_k \end{cases} \quad (2)$$

and  $\alpha_k$  is defined as follows:

$$\alpha_k(v) = \begin{cases} (1+h)a_k & v \leq b \\ \left(1+h \frac{c-v}{c-b}\right)a_k & b < v \leq c \\ a_k & v > c \end{cases} \quad (3)$$

According to our previous approach [5], eq.(2) takes into account the luminance differences among neighboring pixels in order to avoid blurring the image details during noise removal. Unlike our previous method, however, the new function adapts the filtering

action to the local luminance of the pixels (see eq.(3)) in order to gradually increase the smoothing action where the noise is more annoying. This effect typically occurs in the dark areas of the image. The filtering behavior is very simple. As an example, let us suppose  $h=0$ . In this case  $\alpha_k=a_k$ , and the filtering action directly depends on the value of  $a_k$  (see eq.(2)). Large values of  $a_k$  increase the noise cancellation, small values improve the detail preservation. When  $h>0$  (generally  $h \leq 3$ ) the smoothing increase defined by (3) is gradually applied to the low-luminance regions of the image. It should be observed that parameters  $b$  and  $c$  are not critical and can be assigned by the user (typically  $10 \leq b \leq 100$ ,  $b < c \leq 150$ ). Conversely, the optimal choice of  $a_k$  ( $k=1,2,3$ ) is performed by resorting to an automatic procedure.

### 3. PARAMETER TUNING

The procedure for finding the optimal parameter values is based on our previous method that takes into account the mean square error (MSE) between subsequent pairs of processed images [5].

Experimental results have shown that this technique can successfully be extended to the R, G and B channels of a color image. Let  $\Delta\text{MSE}(j)$  briefly denote the mean square error between the noisy channel  $k$  filtered with  $a_k=j$  and the same channel filtered with  $a_k=j-1$  ( $j=1,2,\dots,L/4$ ).

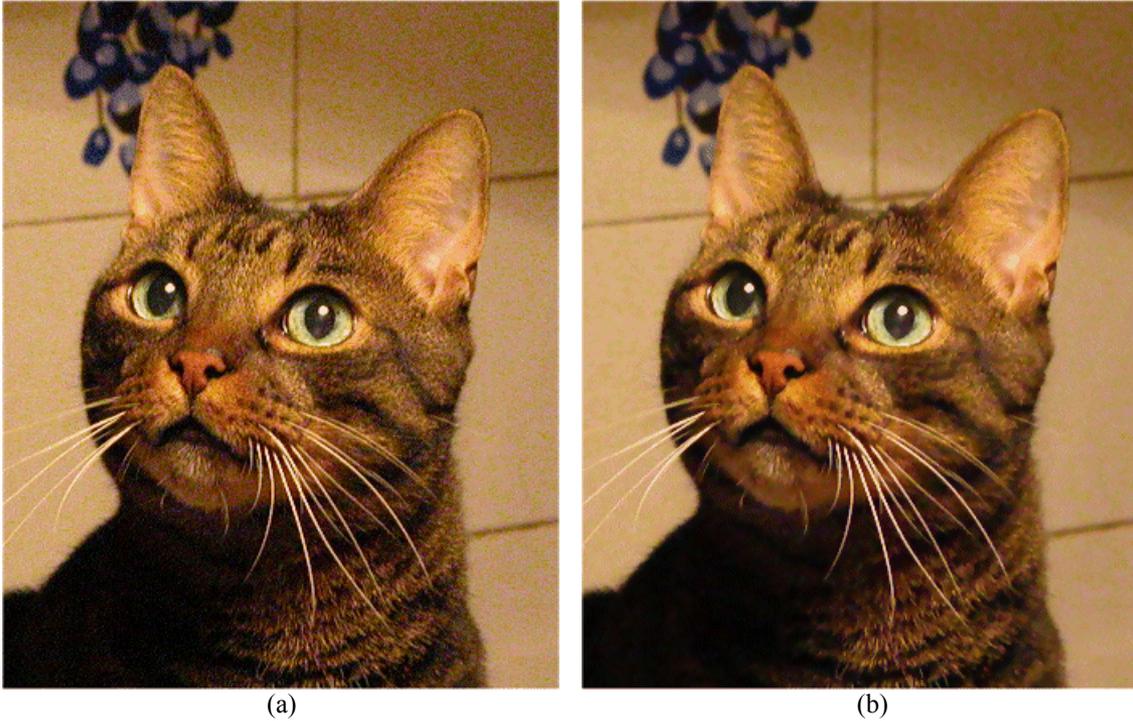


Fig.3 – Noisy image (a), result of the application of the proposed method (b).

The basic procedure for filtering each channel can be summarized as follows:

- 1) set  $h=0$ ;
- 2) find  $j_1: \Delta\text{MSE}(j_1)=\text{MAX}\{\Delta\text{MSE}(j)\}$ ;
- 3) evaluate the estimate  $\hat{a}_{k1} = \hat{a}_{k1}(j_1)$ ;
- 4) process the channel by setting  $h=2$  and  $a_k = \hat{a}_{k1}$ ;
- 5) use the resulting image as input data and set  $h=0$ ;
- 6) find  $j_2: \Delta\text{MSE}(j_2)=\text{MAX}\{\Delta\text{MSE}(j)\}$ ;
- 7) if  $j_2 < j_1$  evaluate the estimate  $\hat{a}_{k2} = \hat{a}_{k2}(j_2)$  and process the image channel by setting  $h=2$  and  $a_k = \hat{a}_{k2}$ .

#### 4. IMPROVING THE NOISE CANCELLATION

The accuracy of the filtering action can be increased by adding a post-processing step that aims at removing noisy pixels possibly still present in the resulting image channels. The output of this filter is defined as follows:

$$y^{(k)}(\mathbf{n}) = x^{(k)}(\mathbf{n}) + \text{MIN}_{i=1, \dots, N} \gamma_k(x_i^{(k)}(\mathbf{n}), x^{(k)}(\mathbf{n})) - \text{MIN}_{i=1, \dots, N} \gamma_k(x^{(k)}(\mathbf{n}), x_i^{(k)}(\mathbf{n})) \quad (4)$$

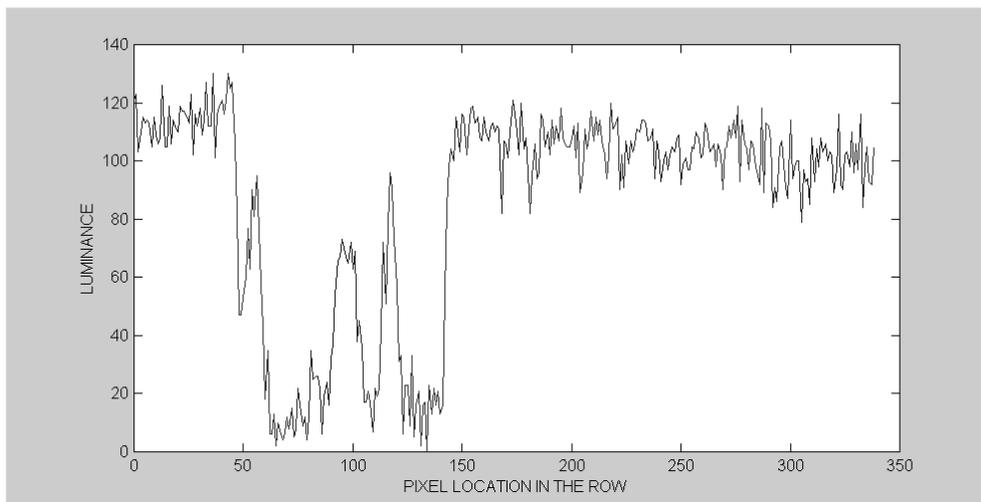
where  $\gamma_k(u,v)$  is a nonlinear function. A possible definition of  $\gamma_k(u,v)$  is given by the following relationship:

$$\gamma_k(u,v) = \begin{cases} u-v & g a_k \leq u-v < L \\ 3(u-v) - 2g a_k & \frac{2}{3} g a_k \leq u-v < g a_k \\ 0 & u-v < \frac{2}{3} g a_k \end{cases} \quad (5)$$

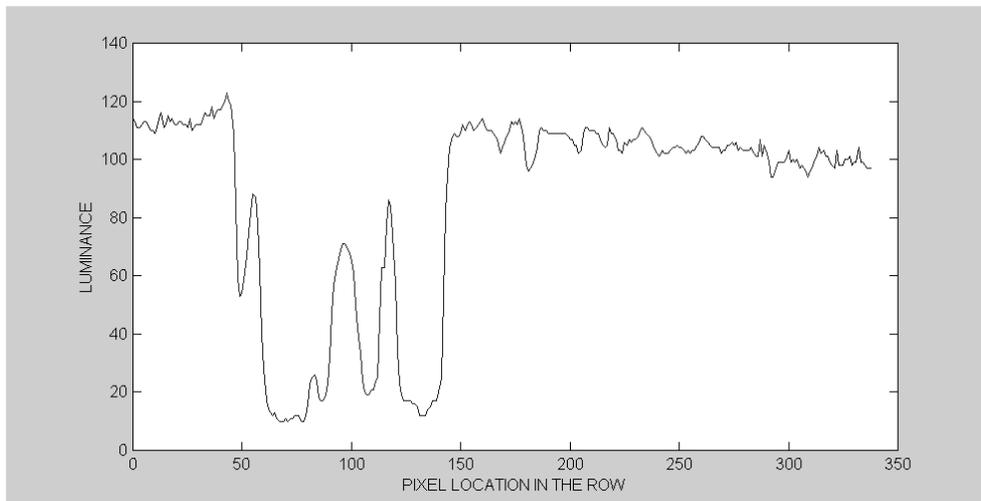
where  $g$  is a parameter (typically  $0 < g \leq 3$ ).

#### 5. EXPERIMENTAL RESULTS

An application example is here reported. Fig.3a shows a detail of a color picture captured by a 5 megapixel digital camera equipped with a 2/3 inch CCD sensor. Since we set the sensitivity to ISO 800 equivalent, some noise is clearly perceivable especially in the dark areas of the picture. The result of the application of our method is depicted in Fig.3b. The noise reduction is apparent, especially in the uniform regions of the image located in the background. Nevertheless, the details look sharp thanks to the detail-preserving mechanism.



(a)



(b)

Fig.4 – Luminances of the noisy (a) and filtered (b) pixels in a row.

In order to highlight the filtering behavior, the luminance values of a row are graphically depicted in Fig.4.

## 6. CONCLUSIONS

A new method for automatic noise removal from color images has been presented. The proposed approach resorts to adaptive nonlinear processing in order to perform a very accurate filtering of the data. Experimental results have shown that the proposed technique is very effective in reducing noise when high sensitivity is chosen during image acquisition from a digital camera.

## ACKNOWLEDGMENT

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