

An improvement of filtering techniques designed to correct the non-uniform illumination effect of images

S. BĂLUȚĂ^{*}, M. ZORAN^a, M. PEARSICĂ^b

The Military Equipment and Technology Research Agency, Aeroportului Street, No. 16, CP 19, OP Bragadiru, 077025, Ilfov, Romania

^a*National Institute for Optoelectronics, INOE 2000, Atomistilor Street, No. 1, P.O. Box MG. 5, Bucharest-Magurele, Romania*

^b*"Henri Coandă" Air Force Academy, IT and Electronic Department, 160 Mihai Viteazu St, 500183 Brasov, Romania*

The quality of some images might be reduced because of non-uniform illumination effect. In order to perform illumination correction, can be successfully used homomorphic filtering techniques. Most of the existing published papers on these methods for image enhancement and/or correction, are restricted to present only the qualitative aspects of this generalized technique. The aim of this article is to develop this subject by computing the appropriate filter's parameters for better monitoring of some image's quality characteristics such as the standard deviation, measured in an image region which is supposed to have a constant reflectance.

(Received August 1, 2008; accepted October 30, 2008)

Keywords: Image generation process, Image enhancement, Image processing, Image quality, Homomorphic filtering, Illumination, Spatial frequencies, Standard deviation

1. Introduction

Generally, we can view an image $f(x,y)$ as a product of two components: the illumination (i) and the reflectance (r). Therefore, the image formation process can be described by equation:

$$f(x,y) = i(x,y) \cdot r(x,y) \quad (1)$$

The resulted image quality may be affected by some degradation factors. Evidently, an inadequate illumination may represents one of these influence factors. For example, for objects with a low level of illumination, the human eye ability to detect them is reduced. This is due to the fact that the contrast sensitivity of the human viewer changes with the viewing conditions [4].

In many cases, an image is presented in a form which is in fact the result of an image acquisition process, performed by a digital camera.

In order to reduce the possible effect of a non-uniform illumination, which can be involved in an image degradation process, some adequate digital image processing techniques can be used. For example, the histogram equalization, which is a usual image processing technique, hasn't a benefic effect in this situation because the resulted image may have a "washed-out appearance" [3]. Instead, in many special papers/articles it is often recommended the using of the homomorphic filtering technique, in order to perform the image enhancement by reducing the non-uniform illumination effect.

2. Optimizing the homomorphic filtering process

The key of the approach is that separation of illumination and reflectance components is achieved. Practically, the homomorphic filter can then operate on these components separately. Illumination component of an image is generally has slow variations, while the reflectance component vary abruptly. By removing the low spatial frequencies (high-pass filtering), the effect realized by the inadequate illumination can be substantially reduced. Evidently, the knowledge of the illumination function model may conduce towards choosing of an adequate filter. This case is reflected in the following picture (Fig. 2).

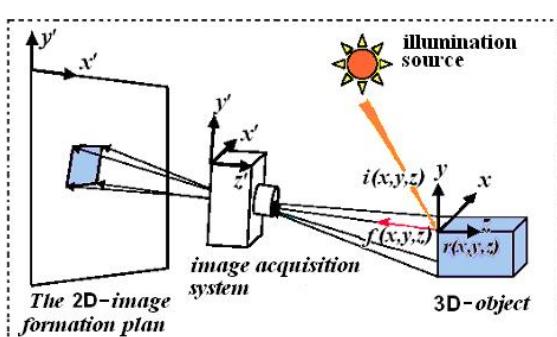


Fig. 1. The basic two components (i and r) involved in an image formation process, performed by a image acquisition system.

In reality, we haven't exact information about the illumination function and, therefore, in order to realize an appropriate filtering process, it is useful to find out a correspondence between the filter election $H(u, v)$ and some characteristics of the filtered image.

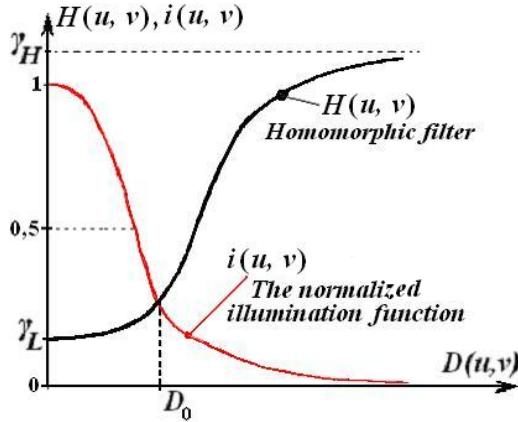


Fig.2. Cross section of a circularly symmetric homomorphic filter and the Fourier representation of the illumination function. $D(u, v)$ is the distance from the origin of the Fourier centered transform.

An adequate filter is based on Gaussian function, described by the bellow equation:

$$H(u, v) = (\gamma_H - \gamma_L)[1 - \exp(-c \frac{D^2(u, v)}{D_0^2})] + \gamma_L \quad (2)$$

Such filter has a particular importance because [3]:

- his shape is easily specified;
- both the forward and inverse Fourier transform of a Gaussian function are real Gaussian function;
- this filter will not introduce a ringing effect.

Usually, the constant noted with c has the value $c=1/2$, and the parameter D_0 which has the significance of a transit frequency, is replaced by the notation σ . Therefore, the relation (2) will become:

$$H(u, v) = (\gamma_H - \gamma_L)[1 - \exp(-\frac{D^2(u, v)}{2\sigma^2})] + \gamma_L \quad (3)$$

Evidently, as it is shown in Fig. 2, the constants $\gamma_L \leq 0.5$ and $\gamma_H \geq 1$, are selected in order to realize the enhancement of high frequencies and, on the other hand, to reduce the low frequencies. The most important parameter of the Gaussian filter is σ . This parameter must be selected such as the resulted *homomorphic filter* will have the effect of a substantial reducing of non-uniform illumination influence. In order to evaluate these influence, it is proposed to analyze the graph $sd=sd(\sigma)$, where sd represents the notation used for the **standard deviation**, measured in a filtered image region, that is supposed to have a constant reflectance ($r \approx \text{ct.}$). The choise of this indicator (sd) is jointed with the fact that, a

high value of standard deviation, mesured in a region characterised with a constant reflectance, denote a high degradation level of the corresponding image due to a pronounced non-uniform illumination.

In order to calculate the standard deviation value, it is used the relationship:

$$sd = \sqrt{\frac{1}{N} \sum_{i=1}^N (x_i - \bar{x})^2} \quad (4)$$

where N is the total number of pixels in the region, $\{x_1, x_2, \dots, x_N\}$ represent the pixels' values (their intensities), and \bar{x} is the arithmetic mean of the pixels' values.

The mentioned process is reflected in the picture bellow; the rectangular region, marked by the points P_1 and P_2 , is that which is supposed to have a constant reflectance.

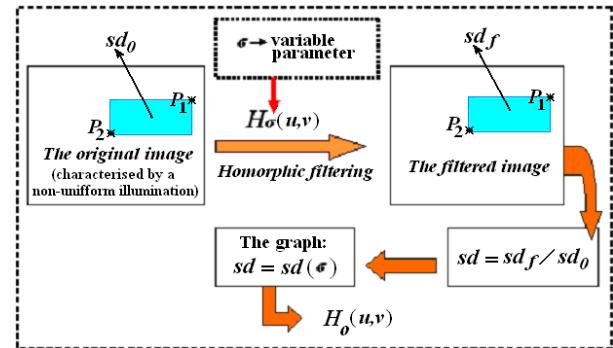


Fig.3. A schematic presentation of the process of getting a adequate homomorphic filter $H_0(u, v)$, by analyzing the graph: $sd=sd(\sigma)$.

It is expected, with the increasing of σ value, to obtain a reducing of the non-uniform illumination effect. Therefore, the standard deviation graph will have a decreasing evolution in rapport with the parameter σ . In the picture bellow, is presented such graph.

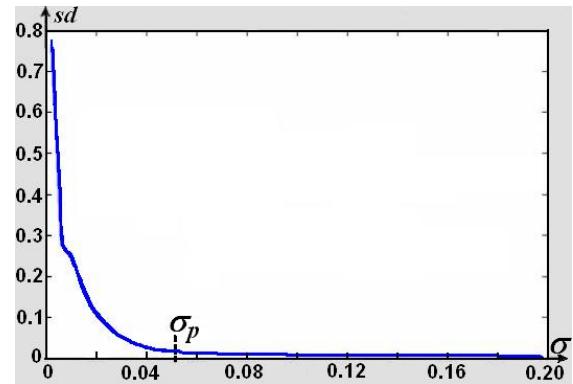


Fig. 4. A diagram example of a standard deviation $sd=sd(\sigma)$, measured in a region with a constant reflectance ($r \approx \text{const.}$).

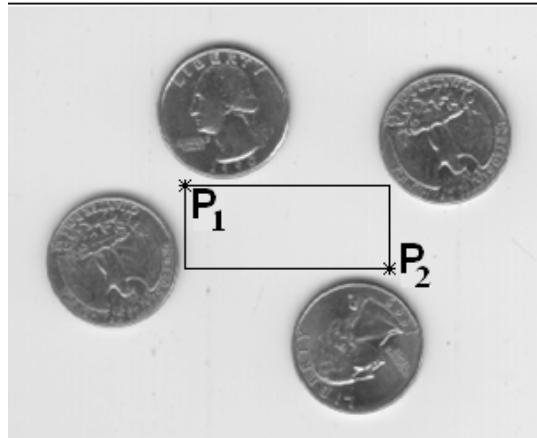
An optimal choice of the parameter σ may be realized in the wake of analyzing of the standard deviation diagram. For example, it can observe that, for the σ parameter values greater than σ_p , the filtering process are inefficient. On the other hand, for the σ parameter values smaller than σ_p , the effect of non-uniform illumination is strongly compensated.

3. Experimental results

For our experiments, was selected an image that has inside a region with a constant reflectance, which is easily to be located. For example, the rectangle marked by the points P_1 and P_2 may be considered such a region.



(a)



(b)

Fig. 5: a) The original image that was selected. b) The region with a constant reflectance, marked by the points P_1 and P_2 .

In order to degrade the selected image, will be used a non-uniform illumination function. Practically, the corrupted image that will result, noted with C , represents

the product between the illumination function (I) with the original image (O):

$$C(x, y) = O(x, y) \cdot I(x, y). \quad (4)$$

As it can observe, the bottom zone in the degraded image has a reduced visibility of the details. The degree of degradation can be evaluated by using some adequate image fidelity measures. For example, one of the most used image fidelity measures is **MSE** (*Mean Squared Error*), defined by the calculation relation:

$$MSE = \frac{\sum_{i=1}^{I_T} \sum_{j=1}^{J_T} [p_{ij} - p_{ij}^*]^2}{N} \quad (5)$$

where p_{ij} , p_{ij}^* represent the pixels' intensity for the original and, respectively for the degraded image, I_T , J_T , represent the total number of rows and columns in the image and N is the total number of image's pixels. Another image quality indicators may be also used, such as **Hsd** (histogram's standard deviation), **mean2** (the arithmetic mean of the pixels' values) and **sd** -which has been presented previously.



(a)



(b)

Fig. 6. a) The degraded image, resulted by using a non-uniform illumination function (b).

As it was mentioned, in order to compensate the non-uniform illumination effect, the *histogram equalization* it is not recommended in this situation.

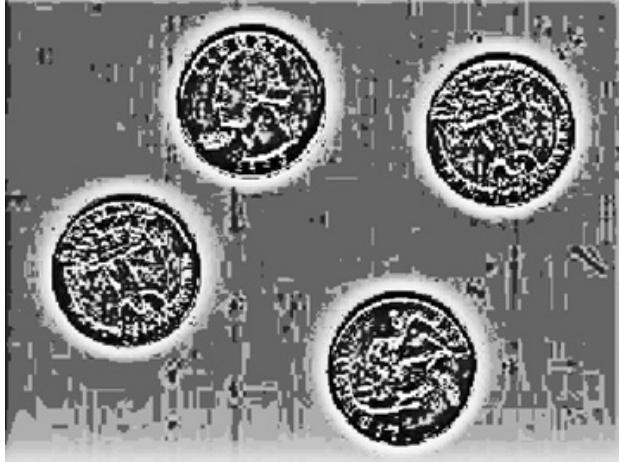


Fig.7. An image with a “washed-out appearance”, resulted by processing the degraded image with the histogram equalization technique.

In order to realize an adequate homomorphic filtering process, it is indicated the analyzing of the standard deviation diagram. In the wake of this analysis, results the value for the parameter σ_p ($\sigma_p = 0.054$). The spatial representation of the resulted Gaussian filter, with the parameters $\gamma_L=0.01$ and $\gamma_H=1.01$, is presented bellow.

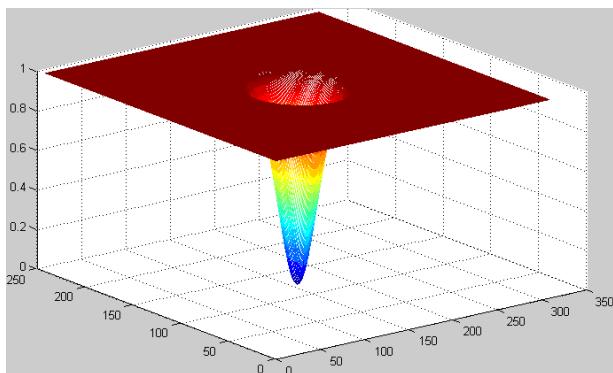


Fig.8. The spatial representation of the resulted Gaussian filter.

By performing the filtering process, will result an image which has a really compensation for the effect of non-uniform illumination.



Fig.9. The homomorphic filtered image.

4. Discussion and conclusions

The homomorphic filtering process is inevitably followed by two undesirable effects: the contrast reducing (there are no sharp differences between black and white) and, on the other hand, the brightness diminution. Evidently, that it is due to the strongly attenuation of low spatial frequencies. The histogram's shape which characterizes the image resulted by performing the filtering process, reflects this aspect, as is illustrated in Fig. 10.

In order to increase the contrast, it is recommended to perform a *contrast stretching*. In this process, pixel values below a specified value are displayed as black, pixel values above a specified value are displayed as white, and pixel values in between these two values are displayed as shades of gray. The result is a linear mapping of a subset of pixel values to the entire range of grays, from black to white, producing an image of higher contrast.

The evolution of images' quality, which are resulted by performing these related image processing techniques, may be monitored by some adequate image's indicators, as is reflected bellow, in the Table 1.

Table 1. The evolution of some image quality indicators.

image indicator	Degraded image	Filtered image	Contrast adjusted image
mean2	0.387	0.1296	0.344
Hsd	0.0019	0.0301	0.0246
MSE	0.223	0.4645	0.2346
sd	$4 \cdot 10^{-3}$	$4 \cdot 10^{-3}$	$34 \cdot 10^{-4}$

The following picture reflects the reducing contrast effect, resulted in the wake of a homomorphic filtering process. As it can observe, the corresponding histogram of the filtered image (b) is narrower.

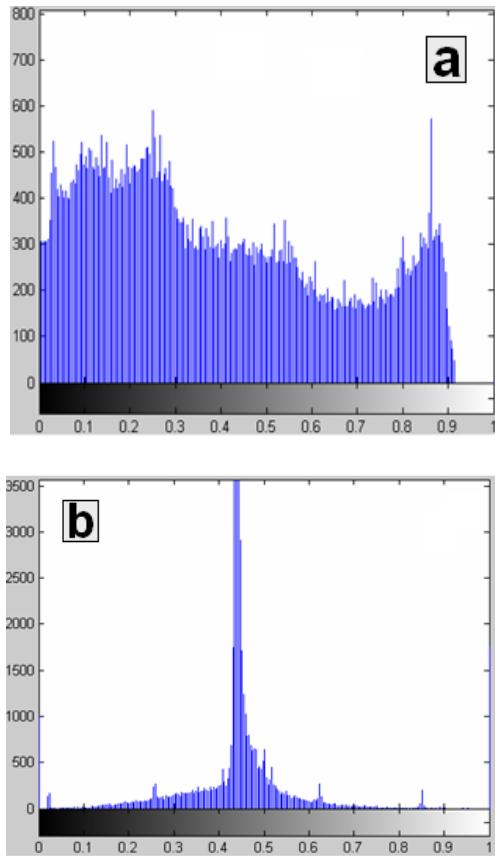


Fig.10. The corresponding histograms (a) of the degraded image (before filtering process) and respectively, of the filtered image (b).

References

- [1] I. Avcibas, B. Sankur, K. Sayood, Journal of Electronic Imaging **11**(2), 206 (2002).
- [2] Ahmet M. Eskicioglu. Thomson Cosumer Electronics; <http://www.sci.brooklyn.cuny.edu/~eskicioglu/papers/ICASSP2000.pdf>.
- [3] R. Gonzales, R. Woods, "Digital Image Processing". Addison Wesley, 1993.
- [4] P. Sprawls, Ph.D., "Image Characteristics and Quality". <http://www.sprawls.org/ppmi2/>
- [5] P. Zamperoni, Advances in Imaging and Electron Physics, Academic Press **92**, 1 (1995).
- [6] ***, <http://www.machinevisiononline.org/public/articles/cognex1.PDF>: "An Introduction to Digital Image Processing".

*Corresponding author: baluta.silviu@yahoo.com