Partially Blurred Light Microscopy Image Restoration

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***Abstract*—Blur is a natural issue in imaging systems and may be relevant for several fields which rely on image-based analysis techniques, such as medicine, biology and material science. These fields are frequently related to microscopes, optical instruments capable of generating magnified images of small objects and structures. The main causes of blur are motion and defocus. Dealing with this property is a challenging process.**

I. Introduction

BLUR is a natural issue in imaging systems and may be relevant for several fields which rely on image-based analysis techniques, such as medicine, biology and material sciences. These fields are frequently related to microscopes, optical instruments capable of generating magnified images of small objects and structures. This work attempts to restore light microscopy images and compare the results concerning their quality and relative sharpness.

II. Objectives

This work aims to perform image restoration with two different filters: inverse filter and Wiener filter. The quality of the results will be compared quantitatively and qualitatively.

III. Materials

The image database consists of light microscopy images from a sample of *Callisia repens* specimens (known in Brazil as *Dinheiro-em-penca*, acquired with an ZEISS SteREO Discovery v20 microscope, commonly used in biological analysis applications. The images are a courtesy of the *Scientific Computing Group* from the São Carlos Institute of Physics (IFSC), coordinated by professor Odemir Martinez Bruno, PhD. Those images where chosen because the stomata are clearly visible. Fig. 1 represents one image from the database.

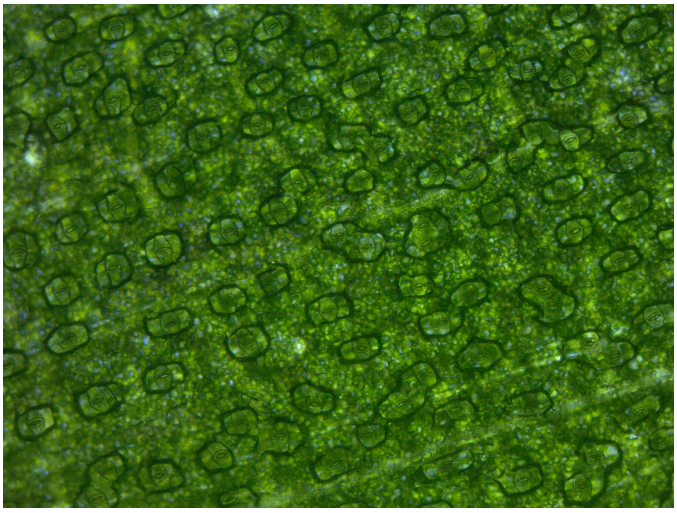

Fig. 1. An image of a *Callisia repens* specimen, magnified 200x.

IV. Methods

The project proposes two different filters for image restoration. For both of them, there will be enhanced quality images (this will be done by the ZEISS acquiring software with *Best Fit* and *Exposure* tools or with GNU Image Manipulation Program - GIMP - tools), considered to be the ground truth for the comparison purposes. Those will be compared with each image of the database, before and after the restoration process. The methods are, as proposed by [1]:

- **Inverse Filtering**: considering the effect of blur in images is caused by a linear process, the resultant image may be described by a convolution of the input image with a function $h(x, \alpha, y, \beta)$, called the point spread function of the imaging device. The process in the continuous domain may be represented by Equation 1

$$g(\alpha, \beta) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} f(x, y) h(x, \alpha, y, \beta) dx dy \qquad (1)$$

Where $g(\alpha, \beta)$ is the degraded image and $f(x, y)$ is the real image. With the above relation in hands, one can infer that it is possible to obtain $f(x, y)$ performing a convolution of $g(\alpha, \beta)$ with the inverse of $h(x, \alpha, y, \beta)$ matrix.
The Fourier domain inverse filtering algorithm considering the limitations of zero division may be expressed by Equation 2:

$$\hat{F}(u, v) = \begin{cases} \frac{\hat{G}(u,v)}{\hat{H}(u,v)} & \text{if } u < u_0 \text{ and } v < v_0 \\ \hat{G}(u, v), & \text{if } u \geq u_0 \text{ and } v \geq v_0 \end{cases} \qquad (2)$$

V. Evaluation

For a quantitative evaluation of the results, the chosen metric is the Root Mean Squared Error (RMSE) between the ground truth images, the original blurred images and the restored ones. This method is supposed to weight the differences between the two images proportionally, and is defined by Equation 3:

$$RMSE = \sqrt{\frac{1}{MN} \sum_{i=1}^{n} (f(x, y) - \hat{f}(x, y))^2} \qquad (3)$$

Where $f(x, y)$ is the ground truth image and $\hat{f}(x, y)$ is the restored image which may be $g(x, y)$ (the degraded image).

VI. Partial Results

Tests were performed with the inverse filtering process and four images of 2560x1920 pixels each. The ground truth images for those cases were enhanced and restored GIMP, with the *Unsharp Mask* tool. The parameters were 200 and 0.5 for radius and amount. The results shown in Table I proves that the inverse filter in fact achieve some amount of restoration, but the effects might not be relevant for a very degraded image.

TABLE I
Partial Results

Image	RMSE(GT, $\hat{f}$)	RMSE(GT, g)
1	0.0755	0.1904
2	0.0708	0.2152
3	0.0831	0.1460
4	0.0667	0.2002

References

[1] Petrou, M. and Petrou, C. *Image Processing: The Fundamentals*. John Wiley & Sons, Singapore, 2nd edition, 2010.