RESTORATION OF NON UNIFORM ILLUMINATION IN COLOR AERIAL PHOTOGRAPHS

Restauração de iluminação não uniforme em fotografias aéreas coloridas

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ABSTRACT

The non-uniform illumination distribution on the negative of aerial photographs can be only done by vignetting or a combination of vignetting with atmospheric factors and bidirectional reflectance. The radiometric degradation that the images present can be corrected by mathematical functions, color balancing methods and histogram manipulation, some of which have already been implemented in commercial programs used in photogrammetry and mapping. However, as the results of this method in use are not always acceptable, there is an interest in developing and perfecting other practical methods that can be used in enterprises. The objective of this work is to show the viability and detailed development for preparation of masks, which are background images that can control and compensate the intensity of non-uniform illumination of photographs. Also the results are discussed in comparison to method of balancing of histograms between adjacent blocks of images that is used in some commercial programs.
Key words: Restoration of images; Vignette; Radiometric degradation.

RESUMO

A não uniforme distribuição de iluminação sobre o negativo das fotografias aéreas pode ser efeito somente de vinheta, ou uma combinação de vinheta com fatores

atmosféricos e de reflectância bidirecional. A degradação radiométrica que as imagens apresentam pode ser corrigida com funções matemáticas, métodos de balanceamento de cores e manipulação de histogramas, dos quais alguns já estão implementados em programas comerciais usados em fotogrametria e mapeamento. Porém como os resultados desses métodos em uso nem sempre são aceitáveis, há o interesse no desenvolvimento e aperfeiçoamento de outros métodos práticos que possam ser usados nas empresas. O objetivo deste trabalho é mostrar a viabilidade e desenvolvimento detalhado de preparação de máscaras, que são imagens de fundo que podem controlar a compensação da intensidade de iluminação não uniforme das fotografias. Também são discutidos os resultados em comparação com método de balanceamento de histogramas entre blocos adjacentes de imagens, usado em programa comercial.
Palavras Chave: Restauração de imagens; Vinheta; Degradação radiométrica.

1. INTRODUCTION

The non-uniform distribution of illumination on a negative is provoked by direct and indirect illumination and by atmospheric factors and construction of lenses. The effect in aerial photographs can be perceived more easily in photo-indices and mosaics. Often it is attributed to vignetting. However, the direction of illumination due to the position of the sun and atmospheric factors provoke an additional effect that is not radially symmetric to the center of the photograph. This compound effect can appear in all scaled photographs.

These problems that were well resolved with the use of filters for haze or anti-vignetting in black and white photographs, is now becoming more critical with the ample nowadays use of color photographs and the more and more disseminated use of orthophoto-maps produced with those photographs.

Also there was the adaptation of the production methodology of the orthophoto-maps, that before demanded that each sheet be produced with only one photograph, but nowadays, using the techniques of digital image processing, can be mosaics of two or more photographs. Now it is demanded that seams not be apparent due to the common differences in tones that exist between neighboring photographs.

The techniques that are already available can resolve various problems, such as reduction of clearness because of haze sun reflection, shiny areas (hot spots) and vignetting effect; with digital image processing for commercial programs (NOBREGA and QUINTANILHA, 2004; LI et al., 2004a; WU AND CAMPBELL, 2004; PAPARODIS et al., 2006), but the results are not always acceptable, that is because the seams are visible or because artifacts appear. On the other hand, there are researches and methods being developed that have presented good results, and can be incorporated into commercial programs. Some of these methods are discussed in LI et al. (2004a).

This work initially shows how it is possible to correct the haze effect in high altitude photographs and then develop a method based on masks that is intended to correct the combined illumination degradation effect of vignetting with the bi-directional reflectance distribution function (BRDF) in color aerial photographs. This degradation provokes darkening and alteration of colors of bluish hue on the borders.

Construction details of a mask are also shown and the restoration results in various photographs. Also with the aim of comparison, mosaics were formed with photographs of original tones, pre-processed with masks and pre--processed by manipulation of histograms. The results are discussed in terms of visual quality and processing time.

2. RESTORATION OF HAZE EFFECTS IN HIGH ALTITUDE PHOTOGRAPHS

A well known effect of haze in photogrammetry is reduction of contrast in photographs taken at high altitudes and in the case of colored photographs creating a uniform blue tone (Figure 1a). The effect is produced by light scattering in the atmosphere even with clear sky and it is increased in the presence of dry or humid haze. As a blue light has a higher index of refraction, its scattering is greater and it becomes more visible (SLATER, 1983; FIETE, 2004). The reduction of the contrast is significant and reduces the visualization of details of the images very much (KRAUS, 1992).

During the taking of the photographs the attenuation of haze effects can be done using a yellow filter placed in front of the lenses that absorbs the excess blue light. In digital photogrammetry the degradation, in digitalized images or those obtained directly from digital camera, can be corrected using graphic processing functions of highlighting, brightness, contrast and color correction. In the results shown in Figure 1b the photograph was corrected with significant attenuation of the uniform blue. The Figures 1c and 1d, respectively, show details of the original image and highlights the details of the features that were used to compensate the reduction of contrast

Figure 1- Photograph with uniform haze and processed with highlight, brightness alterations, contrast and color correction.

a) Original photograph.

b) Photograph after processing.

c) Detail of original photograph.

d) Detail after processing.

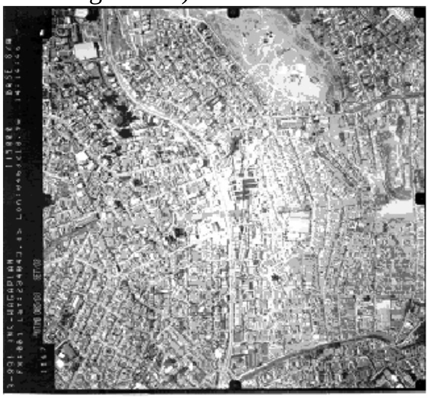
In the processed photograph there still is a blue tone in the borders which results from the vignetting effect which will be discussed later.

3. NON UNIFORM ILLUMINATION IN AERIAL PHOTOGRAPHS

The non uniform illumination in aerial photographs has origin in the vignetting effects, in the directional scattering of solar illumination in the presence of haze and the surface bidirectional reflectance. The vignetting effects come from the non uniform illumination that passes through a lens system until it reaches the negative, being that the amount of light is greater in the center and diminishes at the borders. The effect is radial and symmetrical in the center of the photograph, the borders become darker, and in the case of colored photographs, also becoming bluer. This problem is greater for wide angle cameras, as in the examples in Figures 1a and 2. In Figure 1a only the corners are darker, but in Figure 2 all the borders are darker. In Figure 2b, in black and white, the vignetting effect is clearer.

Figure 2 - Photograph with vignetting effect obtained with wide angle camera. (Photography: Base Engenharia)

a) Colored.



b) Black and white.

As the effect is symmetrical in relation to the center of the photograph, it can be mathematically corrected. A very used function is:

$$1(b) = \cos (b)^n \quad (1)$$

Where: I is illumination which reaches the negative
b angle between optic axis and light ray
N varies from 2.5 to 4 (SLATER, 1983; KRAUS, 1997).

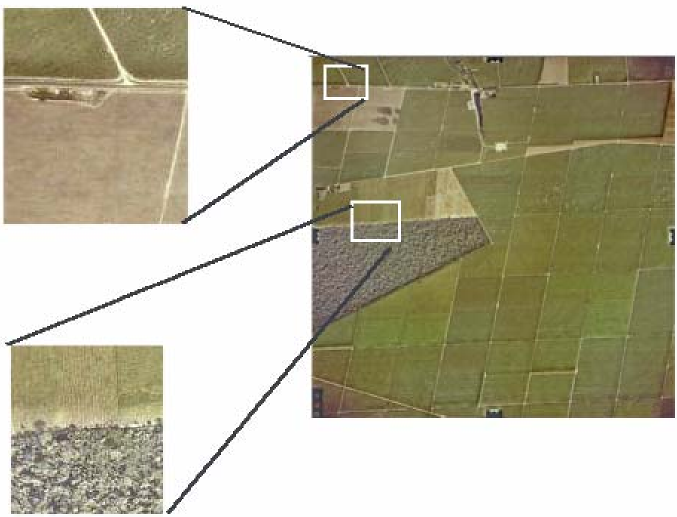
Functions of this kind were used by HOMMA et al. (2000); LAMPARELLI et al. (2004); GONÇALVES (2006) for correction of the vignetting effect in aerial photographs.

4. CORRECTION OF NON UNIFORM ILLUMINATION BY MANIPULATION OF HISTOGRAMS

Among the processes that can correct non uniform illumination in digital images, that are available in commercial programs, the most common is the one that carries out the balancing of histograms between blocks, through statistical equalization. It functions by dividing the original images into blocks, or by sub-images, calculating diverse statistics as global minimum and maximum averages of each block; and processing the histograms , so that it balances the differences of brightness intensity between the blocks. This method can be used as much between photographs of a mosaic as for isolated photographs for correcting vignetting effects, bright areas and BRDF. A description of this method, beside some examples of variation, can be found in LI et al , (2004); PAPARODITIS et al. (2006) and NOBREGA AND QUINTANILHA (2004).

The method, although well diffused, does not always have good results, principally if the photographs or photographs of areas present significant differences, or brusque variations in tonalities. This problem can be seen in examples shown in (NOBREGA AND QUINTANILHA,2004; LI et al., 2004a; WU AND CAMPBELL, 2004). In PAPARODIS et al. (2006) the question is discussed about a mosaic with dozens of photographs. Figure 3 shows an example of a photograph processed with a commercial program. The amplified details show the color gradients that appear in the transition zones between clear and dark features in the images, as between different kinds of vegetation.

Figure 3 - Photograph processed with commercial program using statistical equalization in sub-images, showing transitions between areas with significant tone differences. (Photograph: TOPOCART S/A)



5. CORRECTION OF NON-UNIFORM ILLUMINATION WITH MASKS

The masks in image processing are binary images or gray tones, that are used for delimiting areas where certain operations can be carried out, or to control the degree of processing that it could go through. Examples of binary image masks are the delimiting polygons of each of the images that are to form mosaics (as the roypoli function of the ENVI ® software). Masks in gray tones are already used by photographers and the graphic industry for attenuating shadows of scenery and ambient. Programs such as the ADOBE PhotoShop® have their own functions for constructing and using masks.

However, as these resources have not been used in photogrammetry, an analysis of the viability of use of masks is done for correcting non uniform illumination in aerial photographs. For this, initially, a complete sequence of a mask construction will be detailed.

A mask should represent the mean illumination intensities of the combined effects of vignetting and DBRF. Considering that the variation in luminosity that reaches the plan of the negative does not vary significantly between the photographs of the same area or when taken in a short space of time, a mask should suffice for processing a group of neighboring aerial photographs.

For the construction of a mask at this phase of the work only one photograph was used, but it could have been better if another had been used, because the result would have been free of differences in the tonality of the scenery. The process can start with profiles of gray values of the pixel in lines and columns along the borders, in the center, and intermediate regions; or still by using averages of sub-blocks. This latter process better eliminated the high frequencies and was adopted. Then using polynomial regression of a cubic function, as in equation 2, an adequate fitting for a uniform surface is obtained, without brusque changes:

$$Z(x,y) = A+By+Cy^2+Dy^3+Ex+Fxy+Gxy^2+Hx^2+Ix^2+Jx^3 \qquad (2)$$

Where: x,y are coordinates of the points equivalent to the positions of the pixels or centers of sub-blocks

Z(x,y) is the ordinate in the x,y position

A to J are the coefficients obtained with a sample entry.

As the coefficients of the equation 2 depend on the sample, it is to suppose that the masks constructed with images of the regions with lower variations of tonality in the scenery, better represent the innate differences of illumination.

During the development of this work, masks using diverse programs were constructed in various combinations, as DELPHI®, MATLAB®, EXCEL®, SURFER®,ADOBE Photo Shop® and PWP- Picture Window Pro®. The masks can be constructed in diverse ways, in accordance with the available resources, but for a commercial production ambient it is more convenient that they are developed and are applicable in language as C++.

The masks used in this final phase were obtained by the steps below:

1. Transformation of colored images into gray tones at levels of 0 to 255.

2. Division of image into five parts along the lines and columns, forming a grid of 5x5 (25 blocks) taking care to eliminate the margins and the fuducial marks.

3. Calculation of mean intensity of each of the 25 blocks and register the minimum and maximum levels.

4. Formation of an NSM (Numeric Surface Model) of 5 x 5 with XY coordinates equally and arbitrarily spaced, since only the relative positions are of interest. The values of Z are the mean intensities calculated in step 3.

5. Interpolation of Z values with a quadratic function using SURFER program.

6. Generation, with Surfer, of an interpolated surface image with completion of level curves and exported in TIF format. Observe that the SURFER associates the black to the minimum level (zero level) and the white to the maximum value (level 255) which differentiates the minimum and maximum values registered in step 3.

7. Adjustment, with the PWP software, of TIF image tones to real minimum and maximum levels noted in step 3. This avoids subsequent adjustments to brightness and contrast that are made by trial and error.

8. Transformation of image on negative and trimming according to X axis (due to differences between coordinate systems of original image and system adopted by SURFER program). Now the mask is concluded.

9. Addition of mask separately to each RGB band and recomposition of image. If the graphic program permits it can be added directly to the colored image.

10. Finally a program for adding heightening contrast and brightness of image is carried out.

A mask produced with the above sequence is in Figure 4.

Figure 4 - Example of mask.

One of the processing results with individually added mask to the RGB bands of Figure 5a is shown in Figure 5b. The very dark tonality in the inferior part was corrected and the topographic features became clearer. The colors of the darker parts are not well recuperated principally if they were saturated. This problem is the object of investigation in the continuity of this work.

With the aim of comparison, the block balancing method was applied to the same photograph and the result is in Figure 5c, where it can be seen that the mean tonality of the image is more uniform, but the inferior part is still very dark, besides presenting the artifacts already shown in Figure 3.

Figure 5 - a) original mask b) recuperated with mask. c) Recuperated with block balancing.

a) b) c)

The method of mask addition besides not introducing artifacts and undesired color transitions is computationally more efficient, since the same mask can be used in many photographs taken at a certain interval of flight time, as in the strip (Figure 6b and 7b). Besides this, the process of adding original image with the mask is quicker than the processing of the multiplications and divisions involved in other methods. For an image of 11500 x 11500 (pixels) and blocks of 100 x 100; the total time was 3min 40s with equalization of histogram; and only 1min 10s with mask, on the same computer. The preparation time for the mask depends on the program used, but it can be totally automated.

With pre-corrected images the resulting mosaics have greater tone uniformity, conforming to what can be seen in Figures 6 and 7 that show strips formed with original images and with images pre-corrected with masks.

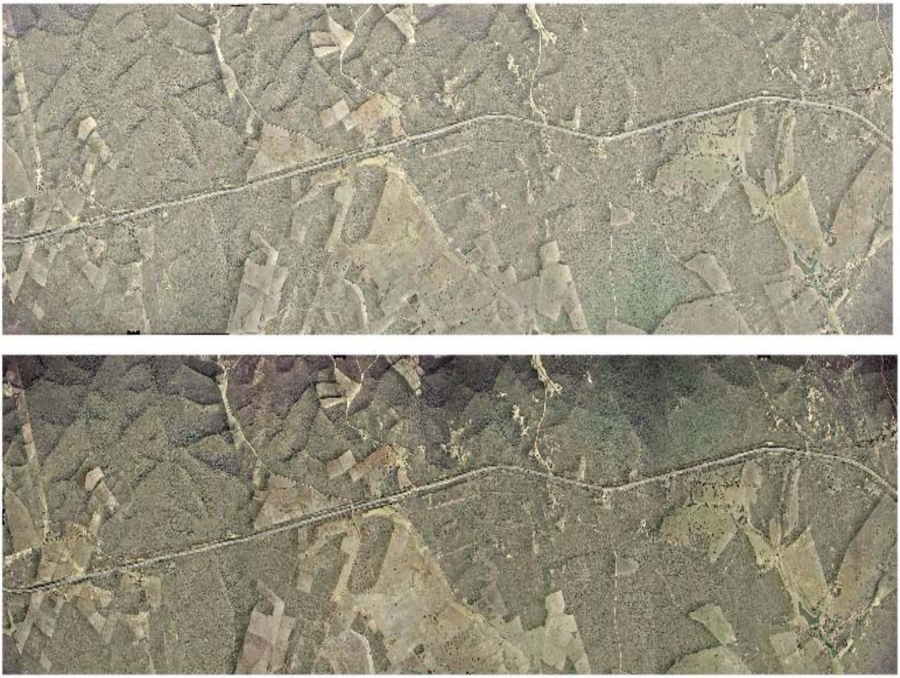
Figure 6 - Example 1 of mosaic strip. a) With pre-processed images. b) With rough images. (Photographs TOPOCART S/A).

Figure 7 - Example 2 of mosaic strip. A) With pre-processed images. b) With rough images. (Photographs TOPOCART S/A).

In the results of processing with masks (Figures 6a and 7a) some difference in tonality can be seen in the emended zones, yet. This could be due to the use of a single photograph for preparing the mask that influenced the features of the land. Ongoing tests show that an average mask obtained from more than one photograph represent, with more accuracy, the combined illumination effects of the BRDF, haze and vignette.

However, the greater uniformity of tones observed in the images processed with masks is already enough for significantly improving a mosaic that is reprocessed with block balancing, as shown in Figure 8a. There is a greater uniformity of tones in Figure 18a, while in Figure 18b there are still areas with more shadows.

Figure 8 - Mosaics processed with block balancing. a) Photographs pre-processed with masks. b) Original photographs. (Photographs: TOPOCART S/A).



Various tests of mask use in colored aerial photographs were done with rural and urban sceneries and varied scales, and the following was observed:

- The correction works well for images that have no variation of texture and tonality in significant scenery, which was expected, considering that the masks were made using only one photograph and not an average of various.
- The colors in the borders of the original images that are saturated are not recuperated.
- The processes of decomposition and separate correction of the R,G,B bands with a mask, or the addition of the colored image give the same result.
- In case the mask is added to the HSV decomposition component V, the recomposed image keeps the tone of the areas of more altered saturated hues (alteration of hue) than in the processing with RGB bands.

6. CONCLUSIONS

The non uniformity of illumination of photographs comes from the combination of atmospheric and vignetting effects and not only vignetting. However, non uniform illumination is not always symmetric in the center of the photograph and cannot be corrected automatically with direct use of mathematical formulas.

The method of mask construction corrects the combined effects of haze and vignetting. It , also, presents advantages over balancing methods with partitions of blocks of the image, that have been used for correcting and balancing colors between photographs in some commercial programs so as not to create artifacts and have a significantly lower processing time.

The mask method does not correct the blue effect on the borders of the photographs or the saturated hues, this matter will be dealt with in the continuation of the works.

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