DODGING IN PHOTOGRAMMETRY AND REMOTE SENSING

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ABSTRACT:

The images in photogrammetry and remote sensing applications are always degraded images. The degradation lies in two aspects: geometry degradation and radiometry degradation. Aimed at the images captured in various scales, the causes of uneven illumination and uneven color are analyzed. Then, the definition of dodging is extended as a process removes uneven illumination and uneven color, eliminates obvious color cast, and improves the realistic representation and geometry quality effectively. However, the main approaches for dodging currently are all merely perform the task of balancing illumination without take into account other factors. After compared and analyzed such approaches, introduced multi-scale retinex for color rendition, and made an assumption of grey world, a framework for color image dodging only based on image information in photogrammetry and remote sensing is proposed and tested. The experiment indicates that such framework can process uneven lightness, uneven color, obvious color cast effectively and restore geometry degradation in a certain degree.

1. INTRODUCTION

In the applications of photogrammetry and remote sensing, the photos are obtained in various carriers at various scales. The images can be classified into remote sensing image, aero-borne photo and close range image based on imaging scale. The carrier of remote sensing image usually is satellite or space shuttle. The carrier of aero-borne photo is usually the aeroplane or other crafts. The close range image is captured by camera in hand or vehicle-borne sensor, camera or video camera. In the process of imaging, each relevant element will affect the final image. According to the path of light propagation and perception, such affections can be arranged as following:

(1) Illuminant. In photogrammetry and remote sensing, the illuminant of imaging is always the sun (close range image may be captured indoor). As to the sun, the difference of imaging time indicates the change of light direction and the color temperature of the illuminant. The direct affection of the change of light direction is that the intensity of the illumination in the scene and the incident angle are changed. The direct affection of changing the color temperature of the illuminant is that the spectra distribution of the illuminant is changed. Thus, the reflectance spectra of the same surface in the same scene will be changed, which will make the image different.

(2) Propagation medium. The primary medium in photogrammetry and remote sensing is the atmosphere. The affections of the atmosphere on image are different in different scales. Generally, the weather variation between multi imaging times, the variation of the clouds and the atmosphere turbulence etc. are primary factors, which will change the illumination spectra on the surface in the scene.

(3) Surface characteristic in the scene. Different physical characteristic will obtain different selective absorption of the illumination spectra. While different geometry characteristic will cause the interaction of multi surfaces.

(4) Imaging device. The optical system diffraction, the non-linearity of sensors or films, the aberration of the optical system, the relative movement of the imaging device and object in the scene all will cause the change of illuminant spectra and the lightness distribution in the image.

Such affections will cause the degradation of the imaging result, which lies in two aspects, geometry degradation and radiometry degradation. The presentation of the former is mostly edge blurring, noise and geometry distortion. While the presentation of the latter is mostly uneven lightness, uneven color, and obvious color cast.

The most intuitive approach is to build a degradation model. However, the building of the model is various. Wu and Danaher [Wu, 2001; Danaher, 2001] built a physical model based on the ground reflectance. Guo [Guo, 2000] built a model based on the radiometry characteristic of the image and imaging geometry relation. More literatures [Tian, 1999; Wang, 2000; Chehdi, 1993; James, 1983; Zhou, 1999; Hu, 2004; Zhang, 2003a] proposed some approaches in the view of image restoration and image enhancement based on the image feature. However, they can’t solve all the problems simultaneously. The definition of the dodging in such literatures is limited in dodging lightness and color, without the realistic of color rendition. But presently, with the development of the device and technology in image capturing, display, and output, the request of realistic image reproduction in the task such as image interpretation and analysis is enhanced at the same time. Color as an attribution is more and more important in photogrammetry and remote sensing, computer vision, machine vision and other areas. Therefore, develop an approach to solve the problems above is very important and meaningful.

Aimed at such problem, in this proposal, section II describes the two primary directions on such topic in detail and indicates the new definition of dodging in photogrammetry and remote sensing. Section III relates the approach based on physical model briefly and points out its availability. Section IV introduces primary approaches about dodging based on the characteristic of the image itself currently, analyzes their function, and points out their availability. Section V proposes a new framework about such topic. Section VI is concerned with its application to real data and the analysis on the result.

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2. BACKGROUND

It should be noticed that the image discussed here are all captured in visible spectra bands, not relating to multi-spectra or hyper-spectra.

For remote sensing image, the problem discussed above is relative to radiometry correction closely all the while. The task of radiometry correction is to build the quantitative relation between the signal quanta of each unit of the sensor and the actual ground object radiometry quanta the pixel correspond to the unit, develop the correction coefficient of the sensor directly, and realize the radiometry correction on the acquired data. Based on the causes of radiometry distortion, the radiometry correction can be performed in three directions. They are atmosphere correction, sensor correction and the correction for the distortion formed by the solar altitude angle and terrain affection. In physical sense, build a model that describes main elements in the imaging process can accurately and effectively restore the radiometry characteristic of the ground undoubtedly. A lot of researches have been performed on this topic, which includes building ground radiometry field [Zhang, 1995], atmosphere radiometry correction based on image [Tian, 1998], radiometry correction based on terrain [Yan, 2000; Li, 1995], and so on. It's obvious that the ideal atmosphere radiometry correction and reflectance inversion should only make use of image information, instead of measuring support data in fields, and is practicable for history data and desolate area. Hence, although restore the surface spectra characteristic in the scene accurately should build a precise and complete model for quantitative remote sensing, for a mass of image analysis and applications such as photo interpretation, 3-D reconstruction, and feature extraction, accomplish the task of radiometry correction conveniently and effectively is still significant.

Additional, for aero-borne image and close range image, the image degradation may directly affect the applications such as visual inspection, image retrieve, texture mapping and mosaic etc.. Because the imaging scale is relative smaller than remote sensing image, this two kinds of images are affected less by atmosphere relatively, but more by the geometry structure of the imaging scene. Therefore, building an illumination model to take into account all factors in the imaging process completely is difficult. Additional, with the improvement of the resolution of the sensors, the differences on resolution between kinds of scales become not significant any more. So, building a model or application framework only based on the image information and is available in most images is significant.

Therefore, in the view of data type and affection factor, processing the affection on imaging scene formed by illumination environment usually has two directions. The first is to build a model. The second is to restore based on image information. And the latter is the main problem we considered.

With the development of image capturing device, displaying device and output device, the application request on image realistic reproduction is improved too. So, the definition of dodging in photogrammetry and remote sensing should be extended to include color restoration, which means the problem dodging processed includes uneven lightness, uneven color, obvious color cast, realistic reproduction and geometry degradation to obtain realistic image suitable to human vision psychology feature and physical feature, instead of conventional uneven lightness.

3. DODGING BASED ON ILLUMINATION MODEL

Strictly speaking, the approaches based on physical model can deal with not only the dodging problem. In areas such as computer vision, machine vision, computer graphics, etc., building an illumination model can simulate the illumination environment to re-rendition the scene, including dodging and obtaining the representations in various illumination environments. So far, literatures indicate that the building of illumination model can performed in three directions: conventional illumination model, complete plenoptic function without illumination model, and image based rendering. [Shen, 2000]

3.1 Conventional Illumination Model

After obtained the description on illuminant, surface reflectance in the scene, transitive characteristic of sensors, and geometry relation of the three elements above, builds a physical model to modify the color of each pixel. That is the basic framework of conventional illumination model [Fournier, 1993; Shum, 2000; Kang, 1999]. Some literatures [Wu, 2001; Danaher, 2001] have brought such method to bear on the radiometry correction on remote sensing data and achieved excellent result. Because the illuminant is mostly the sun, and supposing the ground is Lambertian, the primary task is to computer the bi-directional reflectance distribution function (BRDF). In most applications, take use of conventional illumination model should sample some ground objects' spectra distribution. Because such function is a 5-D function (including wavelength), the sampling and computation are tedious. Although the literature [Shen, 2000] indicates that obtain some BRDF sample of the surface without practical measurement in the field is possible, such as calculates pseudo-BRDF of the surfaces based on the sky light [Yu, 1998], calculate day light spectra from the illumination color temperature based on empirical data [Takagi, 1990], extracts BRDF from the reflect nature of the surface [Jaroszhiewicz, 2003], etc., whether the reflectance data is measured or not, to restore the BRDF of surface in the scene is still a challenging problem. For the applications in photogrammetry and remote sensing, such model can be simplified because the illuminant is ideal and only one - the sun. In remote sensing and aero-photogrammetry, because the objects and terrain affection are various and complex, surfaces, usually is the ground, can be looked as Lambertian, while in close range photogrammetry, the surface is usually the building surface or other special objects, they can't be looked as Lambertian. Therefore, building a conventional illumination model is an effective method in remote sensing image processing with reflectance data measured in field. However, it's difficult in processing image in remote sensing without measured data and in close range applications, which make it be researched in depth in future to obtain practical method.

3.2 Plenoptic Function without Illumination Model

Because to restore the whole scene is a very difficult business, some researchers attempt to build a model to avoid the complex computation in the model building through controlling the variables in the scene and sampling densely. Such attempts take full advantage of the continuity of the plenoptic function. If the variables in the scene are looked as variables in the plenoptic function, a description of plenoptic function in a higher dimension is obtained. Such method without illumination model is equal to restore the continuous expression of that high dimension plenoptic through dense discrete sampling to predict a new view in the unknown illumination environment. [Shen, 2000; Wong, 1997a; Wong, 1997b]

However, for the applications in photogrammetry and remote sensing, such method works less significance, because the dense sampling in multi angles for satellite and aeroplane is too expensive in cost of fund and algorithm. So far, it's not mature method for remote sensing and aero-borne images. But for close range images, it may be a promising method although the algorithm current is not practicable.

3.3 Image Based Rendering

The method based on Image Based Rendering (IBR) is a compromise solution between the two methods above [Shen, 2000; Zongker, 1999; Chuang, 2000]. Such method need neither restore the model information of the scene completely nor interpolate densely. It can be looked as a warp function of plenoptic function because it builds the transfer relation between known plenoptic function and unknown plenoptic function when the scene illumination is changed. The basic idea is developed from Environment Mapping [Blinn, 1976] to Environment Matting [Zongker, 1999; Chuang, 2000]. The idea of Environment Matting takes into account of only the reflection and refraction characteristic of each pixel in the image correspond to the foreground objects instead of conventional geometry model, BRDF and illuminant. It's obvious that the Environment Matting can process specular reflection and refraction excellently and work little on diffusion. Therefore, because in close range, the main problem lies in photos is the different illuminations make the different representations of similar surface of the scene imaging in different time, the method can process applications in close range photogrammetry to dodge between different illumination environments although is should be improved further to take refraction into account.

4. DODGING BASED ON IMAGE INFORMATION

In the applications of photogrammetry and remote sensing, when the scale is large enough to ignore the specular reflection of the surface in the scene or the surface can be looked as Lambertian, such as the ground in remote sensing and some aero-photogrammetry applications, that is to say, when the process only takes refraction, diffusion, and absorption into account, the task of dodging can be performed only based on image information, without calculating the geometry model and reflectance. So far, lots of methods in such direction on the topic of conventional dodging are proposed. Most of them are arranged into 6 typical classes as following.

(1) Simple Template/Model. In some simple applications, an intuitive idea is to build a template to indicate the uneven lightness in the image and to modify each pixel's value based on such template [Zhang, 2003a]. Another typical approach is to build a simple geometry model based on the characteristic of optical lens and to modify each pixel's value based on the geometry model [Milan, 2002]. The advantages of such methods are computation cost few, the main defects are some parameters should be given before processing and geometry quality can't be improved. Additional, the last approach can process only one type of lightness distribution.

(2) Image Restoration. Such approaches consider the solution in the view of image restoration completely. They construct degradation model based on the cognition that when the lightness of the image is balanced, the entropy of the image after processing should be maximum [Tian, 1999; Wang, 2000]. The effect is right, while the defect is computation cost is large. In the literature [Tian, 1999], the algorithm is practice in a chip.

(3) Mask Simulation. Based on the Mask technique in traditional photograph, construct a transparent Mask to restore the geometry attributions and radiometry attributions simultaneously [Hu, 2004]. The effect of balancing lightness and color and geometry improvement is excellent. However, its dynamic range is not improved enough, some detail is lost, and it can't eliminate the color cast in the image.

(4) Homomorphic Filtering. Such applications believe that the illumination is consists of relative high frequency incident light and relative low frequency environment reflect light. Homomorphic filtering can balance the lightness through restraining high frequency part and improving low frequency part [Peli, 1984]. Main defects of such applications are the lost of some detail in low frequency part, compression of the dynamic range, and reduced holistic lightness.

(5) Computational Color Constancy. The improving retinex theory is a very important and promising approach [Land, 1977]. Multi-scale retinex for color rendition (MSRCR) [Rahman, 1996] is an effective version of the theory, which can provide dynamic range compression, color constancy and color rendition simultaneously. Lots of algorithms provide some functions of such aspects. But they can't work in all aspects. In the depiction of relative literatures [Barnard, 1999], it's convictive that such approach can process large mass of data in dynamic range compression, contrast improving, and color rendition effectively and it's a promising approach. However, as to traditional dodging, the effect is not as good as the former approaches.

(6) Other Approaches. Besides the approaches above, literatures indicate that some other approaches can improve dodging effect in some aspects. However, such approaches are almost the development of some algorithm above and the computation is complex. Such as the approach based on wavelet, which is a development of homomorphic filtering. [Zhang, 2001] The former improves the latter aimed at its defect of loss some detail in low frequency area. It splits the image into different frequency parts and improves the quality of low frequency part to keep fine details.

It's noticeable that the first kind of method can be looked as a simplified version of the Mask Simulation. While the Homomorphic Filtering and Mask Simulation can be united into a whole frame like the MSRCR because the MSRCR can process the image in multi scales and in each scale, it control the strength with a Gauss function, which facilitate the unite of the form and the improvement. What's more, except the MSRCR, other approaches all process color images in three channels separately. To obtain a straightforward cognition, a grey image is tested by the five approaches above. The test results are listed following (Fig.1-Fig.6).

To display the difference, the parameters of each algorithm in processing are not tuned to the best value. The examples here are merely for emphasis the main difference on dynamic range compression, lightness balancing, and geometry improvement in each algorithm. Because the images are zoomed in, the description of the compare is listed in Tab.1. Where, L.B. means the effect of lightness balancing. I.R. means the intensity range. G.I. means the geometry improving. C.C. means computation cost. C.I. means the degree of contrast improvement. The number of asterisk means the strength of the indicator.

Fig.1 Origin photo

Fig.2 Simple template

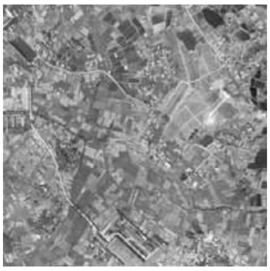

Fig.3 Image restoration

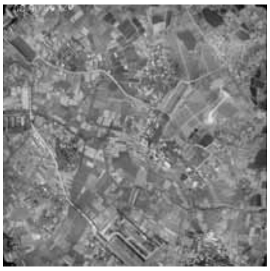

Fig.4 Mask Simulation

Fig.5 Homomorphic Filtering

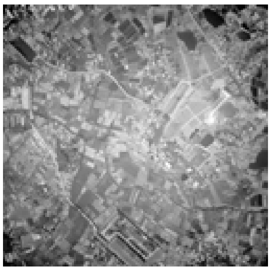

Fig.6 MSRCR

Algorithm	L.B.	I.R.	G.I.	C.C	C.I.
Simple Template	***	*	-	*	-
Image Restoration	***	**	*	****	-
Mask Simulation	***	**	*	***	*
Homomorphic Filtering	**	***	*	***	**
MSRCR	*	****	*	**	***

Tab.1 Compare of 5 main algorithms in 4 indicators

Obviously, each algorithm has its advantages and defects in processing traditional dodging problem. However, when they are tested for color images, only the Multi-scale Retinex can obtain a relative realistic image. The compare is displayed in Fig. 6 to Fig.9.

Fig.7 Origin

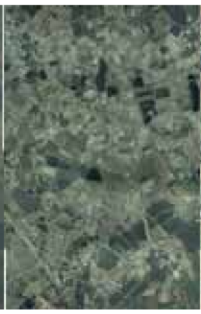

Fig.8 General Dodging

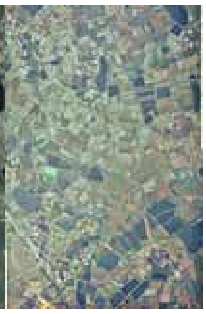

Fig.9 MRSCR

The compare indicates that general dodging algorithm can obtain more excellent traditional dodging effect than MSRCR, while the MRSCR can obtain more realistic effect than general dodging algorithm. Additional, if takes the assumption of grey world [Gasparini, 2004] or makes use of white balancing algorithm, the effect of color restoration can be better.
Therefore, a framework combines the advantage of general algorithm, MRSCR and improves its color restoration ability should meet the extended desire of dodging.

5. A NEW FRAMEWORK FOR EXTENDED DODGING

Based on the analysis above, the task of extended dodging can be performed by four steps: lightness balancing, color rendition, color cast elimination, and geometry improvement. Here the framework proposed is to remove the color cast firstly, and then unites the geometry improvement and color rendition into the framework of MSRCR. The last step is to balance the lightness (See Fig.10). Because color cast elimination will not affect the lightness distribution and the contrast and geometry quality of the image, the color cast elimination is performed firstly. Secondly, because the MSRCR can restore the color and obtain a moderate dynamic range, it's processed secondly.

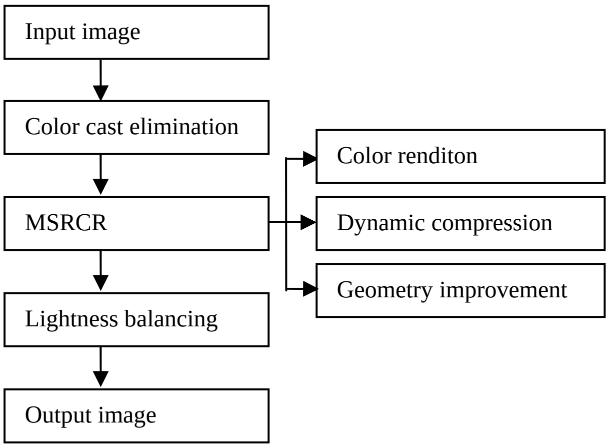

Fig.10 Framework of extended dodging

5.1 Color cast elimination

Because of the changing of color temperature of the illuminant of the scene, the imaging lens' optical feature, and atmosphere affection, the obtained image usually represents an obvious color cast. To obtain a realistic output image, the color cast should be rectified firstly.
Since the imaging scene consists of complex ground objects in remote sensing images and aero-borne images, the assumption of grey world is usually applied. Based on the the Von Kries hypothesis with the RGB channels considered an approximation of the L (large), M (middle), S (small) retinal wavebands [Land, 1971]. The estimate of the sensor scaling coefficients is assimilated within the evaluation of the color balancing coefficients. The diagonal transform is:

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} k_R & 0 & 0 \\ 0 & k_G & 0 \\ 0 & 0 & k_B \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{1}$$

The gain coefficients, k_R, k_G, k_B are estimated by grey world assumption:

$$k_R = GreyR / R_{aver}$$
$$k_G = GreyG / G_{aver} \quad (2)$$
$$k_B = GreyB / B_{aver}$$

Where, GreyR, GreyG, GreyB are the value of grey in the scene. R_{aver}, G_{aver}, B_{aver} are averages of each channel.

5.2 MRSCR

The Multi-scale Retinex (MSR) [Rahman, 1996a] is a generalization of the single-scale retinex (SSR) [Jobson, 1996], which, in turn, is based upon the last version of Land's center/surround retinex. A later version, the MSRCR, combines the dynamic range compression and color constancy of the MSR with a color 'restoration' filter that provides excellent color rendition [Rahman, 1998]. The MSRCR has been tested on a very large suite of images. The Retinex theory assumes that human vision is based on three retinal-cortical systems, each processing the low, middle and high frequency of the visible spectrum independently [Marini, 2000]. The general form of the MSRCR can be summarized by the following equation: [Rahman, 1996b]

$$R_{M_i}(x,y) = F_i(x,y)\sum_{s=1}^{S} w_s(\log[I_i(x,y)] - \log[I_i(x,y) * M_s(x,y)]),\ i=1,2,\cdots\cdots,N \quad (3)$$

Where R_{M_i} is the *i*th band of the MSRCR output, S is the number of scales being used, w_s is the weight of the scale, I_i is the ith band of the input image, and N is the number of bands in the input image. The surround function M_s is defined by

$$M_s(x,y) = K\exp[\sigma_s^2 / (x^2 + y^2)]$$

where σ_s is the standard deviation of the *s*th surround function, and $\iint K\exp[\sigma_s^2 / (x^2 + y^2)]dxdy = 1$.

Fi(x,y) are the color restoration function defined by

$$F_i(x,y) = \log[\frac{I_i(x,y)}{\sum_{n=1}^{N} I_n(x,y)}]$$

However, from the Tab.1, it's clear that the MSRCR can't balance the lightness of the image, although it can obtain a suitable dynamic range, wonderful color rendition and keep geometry information effectively. Then the lightness balancing is needed.

5.3 Lightness balancing

To avoid decreasing the contrast of the image, the methods listed in Tab.1 are abnegated. Here the lightness balancing can be accomplished just by gain/offset rectification in little windows of the image. It can keep the tone information in detail effectively, although the window size is always be given firstly.

6. RESULT AND CONCLUSION

Two origin images above are processed by the framework proposed in Fig.11. Compared with images processed by traditional dodging methods and merely MSRCR, the difference is clear.

However, since the MSRCR can process image in several scales, the lightness balancing should be united into the form of MSRCR. What's more, as a method based on retinex theory, which is describing the human perception on color as an important theory of computational color constancy, the new version should include such functions. It's also the next direction of us in the work for image re-rendition.

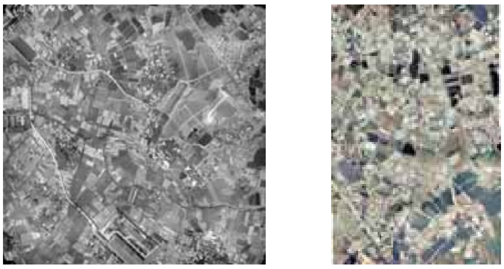

Fig.11 Result of the new framework

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