Enhancement Color Method by Luminance Modulation

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Abstract. Processing outdoor images with low saturated colors is a very complicated task for color based algorithms. Areas such as color segmentation and object classification require to distinguish clearly among regions with dissimilar chromatic features. Some problems with this chromatic discrimination in outdoors images, make it necessary to apply a method for color balancing and image enhancing. In this work, it is proposed an innovative color enhancement method which is based on color modulation; modulation is a function of the original image luminance and it is automatically computed from the same image statistics. This technique has two main advantages: no false colors are created nor oversaturation is presented, for poorly saturated images. In addition, experiments have shown the reliability of the proposed approach.

Keywords: Color enhancement, segmentation, outdoor scenes.

1 Introduction

Color is an important feature for some pattern recognition tasks, e.g., color segmentation, object classification and tracking algorithms. Sometimes images present faded colors due to variable conditions as lighting sources or acquisition devices. Results are not accurate when color segmentation is applied to uncalibrated or low satured color images; because chromatic differences among regions are small. Natural images exhibit rich and complex structure, their colored nature is determined by the physical and geometric properties depending on illumination, reflections and imaging on the scene; color permits to distinguish details that in the original image are not clearly defined. Image enhancement is basically a technology to improve image quality in terms of visual perception of an expert, i.e. human being [1].

Color enhancement algorithms solve these drawbacks and many of them are based on contrast improvement [2]. Therefore, it appears that color enhancement can become

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an important tool for improving the acquisition of powerful color based descriptors for machine vision applications [3]. Image understanding requires segmenting (low level task) a scene into a set of meaningful regions, that is partitioning a natural color image into a set of perceptually color-uniform regions. In this case, if segmentations fails all the further stages could produce unfit results. Limited color constancy strongly affects algorithms, e.g. in outdoor robotics, color must be carefully used and reinforced with some other kind of features (texture, shape, and so on). By the way, in the case of assessing skin lesions in medicine, the expert has to provide a diagnosis whether skin lesion is a serious pathology. For instance he could trust a color analysis by image processing techniques to detect skin lesions such as melanomas. Therefore, color quality enhancement is a fundamental factor for many algorithms based on chromatic features [1]. Nowadays, many techniques for improving image appearance are available and some of them are focused on project details. However, they have important disadvantages: original color changes [4] and lose real appearance of the scene [5]. The main characteristic of the proposed approach [6] is that it permits enhance color to distinguish more easily the difference between regions; all of this without changing the original chromatic information [7].

This paper is organized as follows: a brief state of art in color enhancement is presented in section 2, our approach is presented in section 3, some preliminary results are presented in section 4 and finally the conclusions of this work are discussed in section 5.

2 State of the Art

Image details (e.g. textures) are more evident when the contrast is high (the difference between the smallest and biggest colored pixel in the image), but if contrast is modified, then generally the original color is also altered. Techniques of color enhancement available of improving image appearance (weakly affecting the original chromatic representation) are needed. Moreover, techniques based on histogram modification are frequently used for color enhancement [8]. This kind of techniques modifies the histogram distribution to get an improved image, and good results are obtained in clarity or contrast, but they are not adequate for color processing. Generally, these methods modify each RGB color component without taking into account the correlation among them; this substantially affects the results and the original colors [9].

A color calibration can also be taken further, to ensure the correct analysis (or reproduction) of color as well as intensity. Some other color enhancement techniques have been proposed: based on histogram equalization, contrast enhancement techniques, adaptive neighborhood histograms equalization method and 3D equalization methods in the RGB color space. Some other methods exploit the correlation of luminance and saturation color component of the image locally. Besides some authors exploit genetic algorithms to cope with color enhancement as an optimization problem, as well as multispectral approaches where adaptive strategies for wavelet based image enhancement have also been proposed [1].

Histogram equalization is frequently used for color improvement; in practice this method consists on creating an accumulated histogram, which determines the quantity to be affected for each pixel. In that way, the new histogram is distributed along the desired dynamic rank of pixels. However, the new distribution modifies the value of original pixels assigning them a new color [10], this does not always give good results and object contours are not naturally modified [11]. Displacing histogram is another technique used to make a new image lighter or darker, and it is also based on a arbitrary change of values. Both techniques, equalization and histogram displacing, could be useful in many situations but not in color enhancement or critical color based applications, due to the fact they do not preserve original colors nor maintain color appearance [12] [13]. Retinex is another technique for improving image aspect. It is frequently used when it is not possible to distinguish important details on image. A noticeable improvement is obtained in oversaturated images (Fig. 1). However, it does not work so well with enhance color as it is shown further on.

Usually, some images may require some kind of color enhancement, even if they have been taken by special devices [14]. However, for some applications a short processing time is fundamental and complex algorithms for color enhancement (e.g. multispectral approaches) could be inadequate [15]. Taking into account real-time applications, a technique able to cope with low saturated color problem on images and improve color appearance is proposed in this work. This approach exploits luminance modulation to increase saturation on natural images.

(a) Original image (b) Retinex

Fig. 1. Enhance image using retinex method.

3 Proposed Algorithm

3.1 Image Evaluation

Before applying color enhancement, it is necessary to detect if an image needs to be enhanced, otherwise enhancing an image with good color quality (good saturation) will turn out to be in a new oversaturated and unnatural colored image (Fig. 2). It was defined a parameter, based on the image statistics, to make a decision whether color enhancement must be applied or not. The parameter is the color definition of saturation; we observed that images with good color quality have a saturation factor above of 0.55. On the contrary, images requiring color enhancement have saturation below the factor. In this way, this threshold was established as condition to determine if the color enhancement algorithm must be applied.

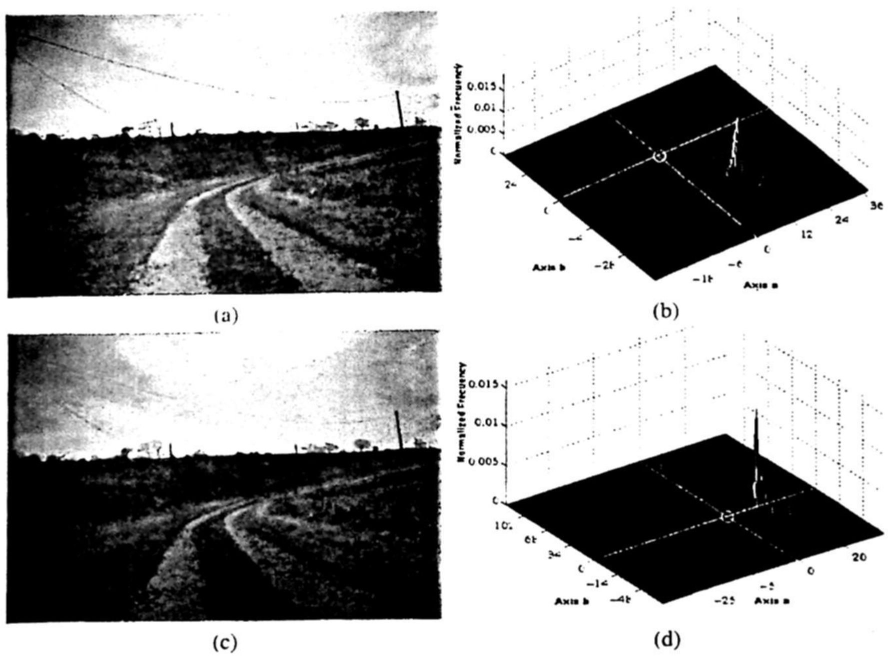


Fig. 2. Oversaturation effect (a)original image (b) output image

3.2 Enhancement Algorithm

The proposed color enhancement method is based on image luminance like modulator element, since luminance (L^3) is closely associated with color intensity. L is taking into account to determine how much the original pixel value must be increased or decreased. Three enhance coefficients ($Coef(R, G, B)$) are calculated, dividing the value of each color band ($BandIn(R, G, B)$) between the luminance of actual pixel ($L(i)$). The biggest coefficient is chosen as the enhance factor ($Efactor$) and dividing each

[3] luminance vector in CIELab space.

coefficient, obtaining enhance quantities. Finally, the original values for each band are multiplied by their corresponding enhance quantities (Ec. 1). The process is applied to each pixel of image.

$$Coef(R,B,G) = BandIn(R,G,B)/L$$

$$Efactor = Max(CoefR, CoefG, CoefB) \tag{1}$$

$$BandOut(R,G,B) = BandIn(R,G,B) * (Coef(R,G,B)/Efactor)$$

3.3 Luminance Adjust

Subsequently, an image is adjusted in luminance to enhance color, it means in color intensity, with the objective to get a better distribution in luminance. This process (Algorithm 1) consists on adjusting only the intensity, not the color; improving in this way the aspect of previously enhanced image. New RGB values must be switched to CIELab space, because it is necessary to work with luminance vector. The process consists on a single adjustment over each pixel, taking into account maximum ($Lmax$) and minimum ($Lmin$) values of L, obtaining the quotient between the differences since $L(i)$ to $Lmin$ and since $Lmax$ to $Lmin$. This means, the adjustment factor is determined based on distance between maximum and minimum, and current pixel value. Later, this result must be affected by the maximum desired value of L, less the minimum desired value of L. Involving all luminance rank, the maximum value is 100 and the minimum is 0. Finally, minimum desired is added at previous result and in this way, it is possible to make a luminance correction.

Algorithm 1: Luminance adjustment.

```
Switch the new RGB values to CIELab space.
Determine maximum value of luminance: Lmax
Determine minimum value of luminance: Lmin
for i=1 until i=TotalPix
  L(i) = (L(i)-Lmin) / (Lmax-Lmin))*100
  if L(i) > 100 then L(i)=100 end if
  if L(i) < 0   then L(i)=0 end if
end for
Switch from CIELab space to RGB space.
```

3.4 RGB Adjust

For luminance adjustment it is necessary to transform again the values from CIELab to RGB space. It must be taken into account that not all values CIELab can be represented on RGB space; it could happen that the values exceed the valid RGB rank (0, 255). This must be avoided because false colors are not desired nor changes on the original information. Again, value adjustment is necessary, but now in RGB space. This avoids producing new colors in the output image, taking into account that we pretend to project actual colors, not new colors. In this way, to adjust existing RGB values it is necessary to calculate the maximum values ($Rmax$, $Gmax$, $Bmax$) and the minimum values ($Rmin$, $Gmin$, $Bmin$) for each band, because based on them, the new correction will be made. Maximums and minimums must be compared, and at the same time, they determine the total maximum and minimum ($Tmax$, $Tmin$). To obtain new desired maximums, it is calculated the quotient of maximum of each band and $Tmax$, and after it is multiplied by the maximum desired value ($MaxDes$). New minimums result from the differences between the minimum of each band and total minimum $Tmin$, added with minimum desired ($MinDes$) and multiplied by the quotient by the same elements. Later, it is made the RGB correction (Algorithm 3), which is similar to luminance adjustment, with the difference that it is applied to each band. The values must not be greater than 255 neither less 0, reason why a verification is necessary. The process described is shown next.

Algorithm 2: RGB adjustment.

```
Determine Rmax, Gmax and Bmax
Determine Rmin, Gmin and Bmin
Tmax=Max(Rmax, Gmax, Bmax)
Tmin=Min(Rmin, Gmin, Bmin)
R_Max=MaxDes*Rmax/Tmax
G_Max=MaxDes*Gmax/Tmax
B_Max=MaxDes*Bmax/Tmax
if Tmin >= 0 then
  R_Min = (Rmin-Tmin+MinDes)*Rmin/Tmin
  G_Min = (Gmin-Tmin+Mindes)*Gmin/Tmin
  B_Min = (Bmin-Tmin+Mindes)*Bmin/Tmin
end if
for i=1 until i=TotalPix
   N_R(i)=((R(i)-Rmin)/(Rmax-Rmin))*(R_Max-R_Min)+R_Min
   N_G(i)=((G(i)-Gmin)/(Gmax-Gmin))*(G_Max-G_Min)+G_Min
   N_B(i)=((B(i)-Bmin)/(Bmax-Bmin))*(B_Max-B_Min)+B_Min
   if N_R(i) > 100 then N_R(i)=100 end if
   if N_R(i) < 0   then N_R(i)=0   end if
   if N_G(i) > 100 then N_G(i)=100 end if
   if N_G(i) <  0  then N_G(i)=0   end if
   if N_B(i) > 100 then N_B(i)=100 end if
   if N_B(i) < 0   then N_B(i)=0   end if
end for
```

4 Experimental Results

Next, the results of color enhancement in outdoor images are shown. The image must be analyzed before any color improvement; this avoids applying enhance color process at an image with a good saturation level. For example, Fig. 2 (a) does not need color enhancement and its shows a blue dominant color visible in the lightest region; if analysis

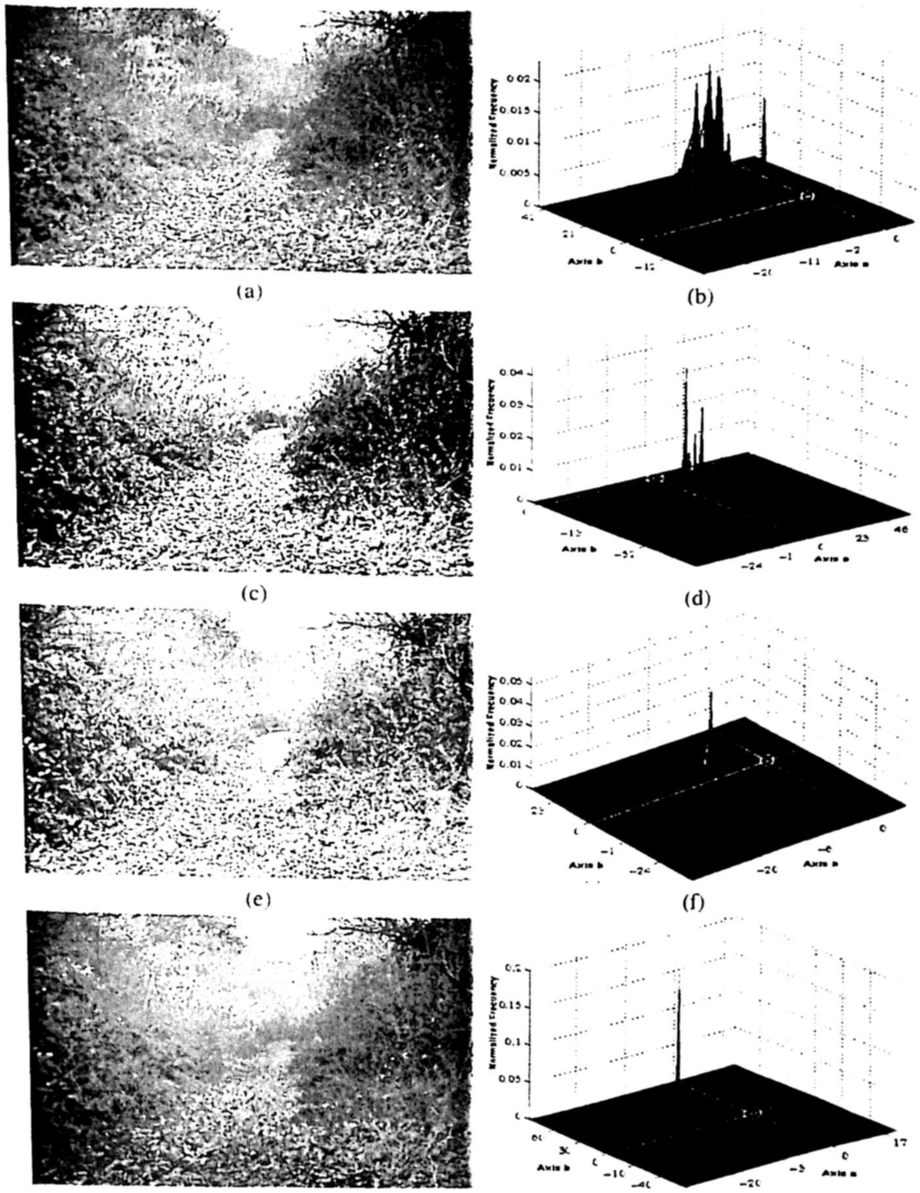
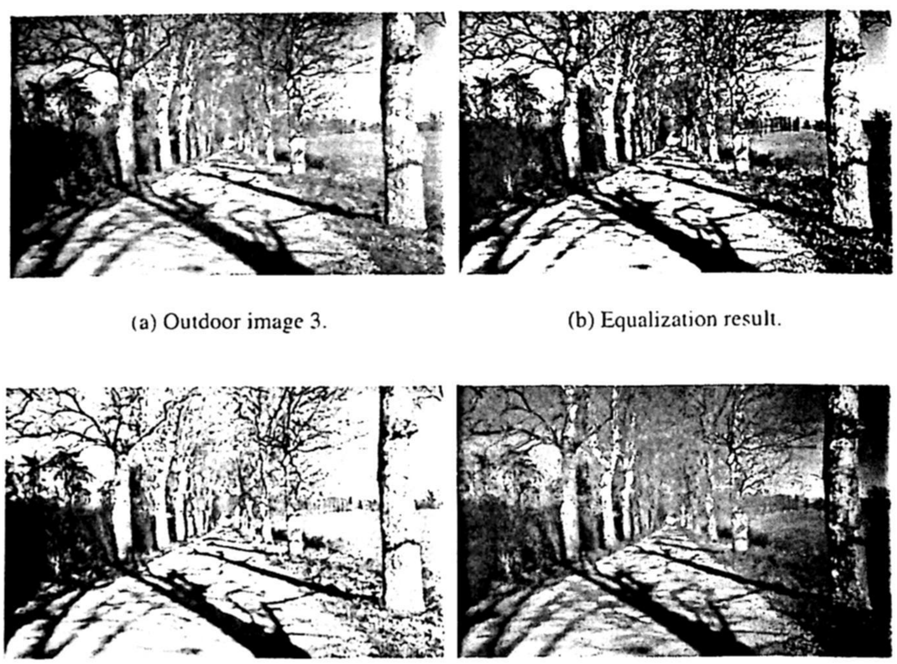


Fig. 3. Color enhancement (a) original image (c) by equalization (e) by retinex (g) by luminance

is omitted, the result is an oversaturated image (Fig. 2 (b)) with an unnatural and excessive color appearance. The histogram center of an image with good saturation is remote of coordinate (0, 0), the central point is the brightest point; it means that histograms very close to (0, 0) have faded colors and histograms very far from it are oversaturated. Neither previous conditions are desired, due to the fact the objective is to obtain a balanced color image with good saturation. As it can be observed histogram of Fig. 2 (b), it is remote to central point, it means image has good saturation level. In this way with the previous analysis this image does not need a color enhance. If the analysis is omitted, then resulting image is oversaturated (Fig. 2 (c)) for which, the histogram is farther from central point. It is not the expected result of a good enhance color method. Otherwise, as we can observe on Fig. 3 (a), the image has good clarity but colors are subdued and it is difficult to distinguish clearly between contiguous regions. Fig. 3 (b)) shows the histogram close to central point, and it is the reason of the grayish and subdued appearance of image.



(a) Outdoor image 3.

(b) Equalization result.

(c) Retinex result.

(d) Color enhancement by luminance

Fig. 4. Outdoor shadowed image

Previously, it was said that equalization is frequently used for improve the image contrast. However, when color improve is desired it is not convenient by reasons mentioned before. Fig. 3 (c) shows the result of equalization and, as it can be observed, the contrast is higher, since it is possible to distinguish more details that in the original image could not be observed. Color is more intense, but the tree zone at the end of road has been loss; it means lost of chromatic information and natural appearance.

Retinex method generally produced grayish colors and lighter image (Fig. 3 (e)), that is not the goal in this case. Previously, it was mentioned that retinex has good results with dark images; it enhances the appearance because it permits to observe details that in the original image are not noticeable. The main disadvantage is the result of low color image, so it is not a good technique for color enhancement.

Fig. 3 (g) shows the result of applying proposed color enhancement by the luminance method. Changes are more notorious and the image looks more attractive (hot colors). The road zone can be clearly distinguished between bushes, such as leaves color are projected among branches. The image was improved in color and false colors were not created; so color was enhanced and the original chromatic structure was maintained. The histogram of the new image (Fig. 3 (h)) shows clearly the difference obtained with the color enhancement method. As it can be observed, it exists a noticeable saturation enhance due to the histogram is now further of central point and this causes than colors are more intense. It implies a color difference reflected on the image. Thus, selection of R band on lighter region in original image, has been balanced with others bands G and B. Other results are shown for outdoor images in Fig. 4.

5 Conclusions

This work was intended to improve image quality with low saturated color, since this preprocessing makes it easier to apply a color based method as well as color segmentation or color classification. Image enhancing by the proposed method can help to improve the results of processes that use color like main feature. This is possible due to increase a better region discrimination with powerful descriptors. Proposed method is based on simple operations, thereby, avoiding an extensive processing and the result is a reliable method; it makes possible a noticeable chromatic enhancement, taking image luminance as the principal element to modulate original color. Keeping original colors appearance is one of the main advantages in the proposed method. Furthermore, the proposed algorithm determines when a color enhancement is required in the image based on the saturation parameter.

References

1. Ding Xiao and Jun Ohya. Contrast Enhancement of Color Images Based on Wavelet Transform and Human Visual System, *Proc. of the IASTED International Conference GRAPHICS AND VISUALIZATION IN ENGINEERING*, January 3-5, 2007.
2. N. W. Campbell, B. T. Thomas and T. Troscianko. Automatic segmentation and classification of outdoor images using neural networks. *International Journal of Neural Systems*, 8(1):137-144, February 1997.

3. C. Fernández - Maloigne, D. Laugier and C. Boscolo. Detection of apples with texture analyze for an apple picker robot. *Intelligent Vehicles '93 Symposium*, pages 323-328, July 1993.
4. J. Huang and D. Mumford. Statistics of natural images and models. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 1(Fort Collins, CO):541-547, December 1999.
5. E. Salvador, A. Cavallaro and T. Ebrahimi. Shadow identification and classification using invariant color models. *IEEE International Conference on Acoustics, Speech and Signal Processing, ICASSP*, volume 3, pages 1545-1548, Salt Lake City, Utah, May 2001.
6. J. W. Hsien, W. F. Hu, C. J. Chang and Y. S. Chen. Shadow elimination for effective moving object detection by Gaussian shadow modeling. *Image and Vision Computing*, 21(6):505-516, June 2003.
7. A. Torralba, K. P. Murphy, W. T. Freeman and M. A. Rubin. Context based vision system for place and object recognition. *Ninth IEEE International Conference on Computer Vision*, volume 1, pages 273-280, Nice, France, October 2003.
8. T. M. Strat and M. A. Fischler. Context based vision: Recognizing objects using information from both 2-d and 3-d imagery. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 13(10):1050-1065, October 1991.
9. G. Finlayson, S. Hordley, G. Schaefer and G. Y. Tian. Illuminant and device invariant colour using histogram equalization. *Pattern recognition*, 30(2):179-190, February 2005.
10. B. Funt and F. Ciurea. Retinex in matlab. *Journal of Electronic Imaging*, 13(1):48-57, January 2004.
11. A. Rizzi, C. Gatta and D. Marini. A new algorithm for unsupervised global and local color correction. *Pattern Recognition Letters*, 24(11):1663-1677, July 2003.
12. G. M. Bianco and A. Rizzi. Chromatic adaptation for robust visual navigation. *Advanced Robotics*, 16(3):217-232, May 2002.
13. C. Poynton. The rehabilitation of gamma. *SPIE Conference on Human Vision and Electronic Imaging II I*, 3299:232-249, 1998.
14. D. Merrill. The next generation digital camera. *Optics and Photonics News*, pages 26-34, January 2003.
15. T. Sakamoto, C. Nakanishi and T. Hase. Software pixel interpolation for digital still cameras suitable for a 32-bit mcu. *IEEE Transactions on Consumer Electronics*, 44(4):1342-1352, November 1998.