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A Review On Different Algorithmsadopted For Image Enhancement With Retinexbased Filtering Methods

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Abstract:
Retinex is a method used for image processing. A computation for color images that approaches to scene observation must combine dynamic range compression, color consistency and color and lightness tonal rendition. A previously designed single-scale retinex (SSR) to a multi-scale retinex (MSR) version that achieves simultaneous dynamic range compression, color consistency, lightness rendition. But this fails to produce good color rendition. To address this problem, the Multi Scale Retinex with Color Restoration (MSRCR) was proposed. The different methods proposed by retinex algorithm includes the multiscale retinex with color restoration, Light Compensation Algorithm in Color Facial Image, Luminance Based MSR algorithm, Adaptive Color Restoration and Luminance MSR, MSR modification to preserve color fidelity while enhancing contrast, Algorithm for MSR method based on modified color restoration, Color image enhancement algorithm based on human visual system based on adaptive filter, Fusion based approach on MSRCR, Color image contrast enhancement algorithm by retinex model, Automated multi scale retinex with color restoration, Enhancement of mammographic feature by multiscale analysis, Nonlinear method to enhance images using improved SSR algorithm, Multi-dimensional multi-scale image processing algorithm, nonlinear multi-scale enhancement algorithm for chest radiography, Ultrasound Liver Image Enhancement Algorithm Based on MSR, Algorithm based on the SSR to enhance the tiny anatomical structures and other regions of interest on the Low-dose CT images. On comparison of original image, SSR image, MSR image, MSRCR image and other image enhancement methods. Finally it is concluded that output of MSRCR is better than other techniques.

Keywords: *retinex, dynamic range compression, color restoration, multi-scale retinex, multi scale retinex with color restoration, single-scale retinex*

Introduction

A common discrepancy exists between recorded color images and the direct observation of scenes. Human perception excels at constructing a visual representation with vivid color and detail across the wide ranging photometric levels due to lighting variations. In addition, human vision computes color so it is color constant. Image enhancement is a method for improving the quality of images for human visualization. Removing blurring and noise, increasing contrast and revealing details are examples of enhancement operations.

A new method for enhancing the contrast of magnetic resonance images by retinex algorithm is implemented. It can correct the blurring in deep anatomical structures and inhomogeneity of MRI. The idea of Retinex was conceived by Edwin Land [1] as a model of lightness and color perception of the human vision. Obviously it is not only a model, but also could be developed to algorithms of image enhancement. Edwin Land coined word for his model of human color vision, combining the retina of the eye and the cerebral cortex of the brain. More specifically it is defined that image processing is a process that automatically provides visual realism to images. Edwin Land introduced a center/surround spatial form, which was inspired by the receptive field structures of neurophysiology. The Retinex is a human-perception based image processing algorithm which provides color constancy and dynamic range compression. The result section contains comparison of original image, SSR image, MSR image, MSRCR image and other image enhancement methods. Finally it is concluded that output of MSRCR is better than other techniques.Retinex has medical imaging application [2] where automatic contrast enhancement and sharpening is needed. Potential areas of impact may include, Digital X-ray, Digital mammography, CT scans, MRI.Telemedicine applications where bandwidth between doctor and patient poses a potential bottleneck. The Retinex compacts the high input dynamic range, potentially reducing the high bandwidth requirement.

Retinex Theory

A human observer can easily see individual objects both in the sunlight and shadowed areas, since the eye locally adapts while scanning the different regions of the scene. When attempting to display the image on a display, either the low intensity areas are underexposed and look black or the high intensity areas are overexposed and cannot be seen. Images taken from digital cameras suffer from a loss in clarity of details and color as it depends on the illuminance which in term varies with distance from source. This problem of Color Constancy in images is solved using the basis of Retinex Theory [3].

There are Single Scale Retinex (SSR) [4] and Multi Scale Retinex (MSR). In SSR instead of applying logarithmic function on the image in order to enhance the range of image signal value, the image signal is passed through the Gaussian filter kind of system called retinex filter. The output of the retinex filter is used only for scaling the original image signal such that the pixel values are scaled by different amounts depending upon the filter output. The scaled down image is then processed with logarithmic function. Since image filtering using retinex function may require different Gaussian shaped impulse response with different variance MSR approach is used.

SSR mathematically expressed [5] as:

$$R_i(x_1, x_2) = \log\left(I_i(x_1, x_2)\right) - \log\left(I_i(x_1, x_2) * F(x_1, x_2)\right) \qquad (1)$$

F is a Gaussian filter defined by:

$$F(x_1, x_2) = k \exp[-(x_1^2 + x_2^2) / \sigma^2] \qquad (2)$$

The MSR can be written as [6]:

$$R_i(x,y) = \sum_{k=1}^{K} W_k . \{\log[I_i(x,y)] - \log[I_i(x,y) * F_k(x,y)]\} \qquad (3)$$

Surround function is:

$$F_k(x,y) = K \exp[-(x^2 + y^2) / \sigma_k{}^2] \qquad (4)$$

The MSR algorithm [7] is a tone-reproduction operator which can achieve color/lightness rendition and dynamic range compression simultaneously. It estimates scene reflectance from the ratios of scene intensities to their local intensity averages. First, the scene is decomposed into a set of images that represent the mean of the image at different spatial resolutions by applying Gaussian filters of different sizes. Next, a set of images that measure the scene reflectance is produced by dividing the original picture point wise by the decomposed picture. Then, a log function is applied to each of the images to reduce the image dynamic range. Finally, the displayed image is reconstructed by adding the compressed images together. In both the approaches the color images get badly affected when the luminance portion of the image is passed through retinex filter, hence post processing has to be done for the retinex filtered color images by using different color restoration procedures.

MSRCR is mathematically given as:

$$R_i(x_1, x_2) = \alpha_i(x_1,x_2) \sum_{k=1}^{K} W_k(\log I_i(x_1,x_2) - \log[F_k(x_1,x_2) * I_i(x_1,x_2)]) \qquad (5)$$

Multi Scale Retinex with Color Restoration (MSRCR) [8] is better approach for color images. Computation like the MSRCR appears to have two very useful properties simultaneously: a diminishment in the dependence of the appearance of the image on extraneous variables such as spatial and spectral lighting, and the construction of compact context relationships.

Methodology

A previously designed single-scale centre/surround retinex to a multiscale version that achieves simultaneous dynamic range compression/color consistency/ lightness rendition. This extension fails to produce good color rendition for a class of images that contain violations of the gray-world assumption implicit to the theoretical foundation of the retinex. Daniel J. Jobson, Zia-ur Rahman and Glenn A. Woodell [9] propose the multiscale retinex with color restoration. This method of color restoration corrects for the deficiency at the cost of a modest dilution in color consistency. Finally by comparison with other image enhancement techniques such as histogram equalization, gamma correction, and gain/offset manipulation [10], and point logarithmic nonlinearity overall, the performance of the retinex is consistently good. But this method fails to produce good color rendition for a class of images that contain violations of the gray world.

Moore, G.Fox, J.Allman and R.M.Goodman. [11], [12] used the retinex as a natural implementation for analog very large scale integration resistive networks and discovered that color rendition was dependent on scene content. So the problem is that some scenes worked well, others did not.

D. Brainard and B. Wandell [13] came up with a theoretical study of retinex based on convergence properties of Land's retinex theory and discovered that the pixel values converge to simple normalization when both path and length keep increasing.

Yali Feng, Jing Huang, Zhuoli Feng and Minyong Liu [14] introduced the fast Fourier algorithm into the original algorithm to make the speed faster than that of the traditional method. The traditional MSRCR is directly convolution filter operations in the airspace [15] [16], which the computational complexity is considerable, lead to the operation time is long. So here in the convolution operation process, they use the fast fourier transform (FFT) to complete convolution operation in frequency domain. Then next adjust the image by gain/offset. The problem held with the method is that it lacks proper dynamic range compression.

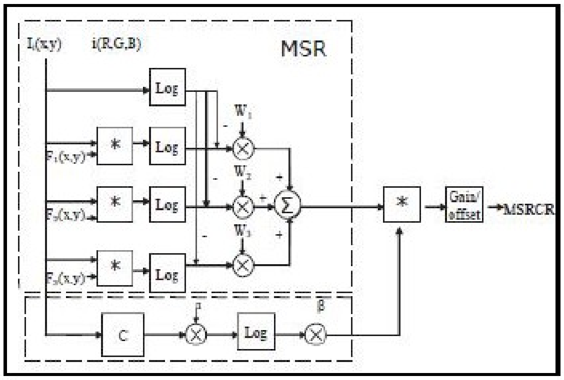

Figure1:Flow chart of algorithm MSRCR

Figure2:(a)Traditional MSRCR
(b) Algorithm of this paper

Bo Sun, Wenjing Tao, Weifang Chen, Hongyu Li, Jiang Li and Wei Guo[17] came up with Luminance Based MSR (LB_MSR) algorithm. The processing is simplified by treating the luminance channel only to avoid incorrect colors and no color restoration is applied. Firstly, process the luminance channel which is obtained by principal component analysis (PCA). PCA provides orthogonality between channels, thus allow the color to remain stable despite the modification of luminance. Secondly, add the convolution results of different scales instead of multiplying the convolution results of each color value and the different scale Gaussian. LB_MSR algorithm maintains color fidelity, and still preserves the contrast enhancement benefits of the conventional Retinex based methods.

Figure3:(a) Original image (b) LB_MSR result

LB_MSR can enhance darker images in the poor lightening areas and could save CPU time largely, but it doesn't work in other images as effectively as in the 'whole black background' images and 'darker objects with brighter background' images. The disadvantage is that the method cannot retrieve fine details and vivid color.Junxuan Yan and Ke Zhang [18] proposed Adaptive Color Restoration and Luminance MSR Based Scheme for Image Enhancement (ACRL_MSR) to improve the visual quality of color images under poor lighting condition. The three color bands are enhanced by adjusting luminance which is automatically enhanced to a proper range based on Human Visual System via the adaptive parameter. ACRL_MSR overcome the drawbacks with LB_MSR. Here First, the luminance of color image is obtained [19]. Having computed the luminance, the basic form of MSR is applied. In order to lower the chance of color noise enhancement, the multiplication relationship of the three convolution results is changed into addition. Then, the pixels are mapped into the output range using histogram based gain-offset method and assure that no luminance drop for each pixel. Then, each channel is set to the same chromaticity. ACRL_MSR tunes the peak values of HIST to distribute uniformly in a range of 0-200. The dark zones with insufficient brightness and contrast in the original images are enhanced by the algorithms. The distribution of luminance values of HIST in bright areas (200-255) is kept unchanged. Then ACRL_MSR creates a non-linear function to best fit the gray levels of tuned peak values in the least-squares sense. The fitted curve for the peak values should be smooth and without degression. Thus all the desired output luminance values are determined according to this fitted curve. After this, the new algorithm computes flexible adaptive constant for each pixel location.

Figure4: Image enhancement comparison: (a) original images,(b) MSRCR, (c)LB_MSR, and (d) ACRL_MSR

The algorithm is observed from the experiment results, which produces more natural and vivid color than those by MSRCR and LB_MSR. The drawback of this method is that it is time consuming.

Brian Funt, Kobus Barnard, Michael Brockington and VladCardei[20] modify MSR so that it preserves color fidelity while still enhancing contrast. They add neural-net based color constancy processing [21] to the modified version of MSR. Firstly, color constancy processing is required, so a sophisticated color constancy algorithm is applied to the image to estimate the proper image chromaticities. The color constancy method corrects for the mismatch between the camera and an unknown illuminant using a neural network. The second step of the algorithm is to apply MSR processing to the image luminance. The next step is to apply the gain-offset method to the luminance. Thus having determined the desired luminance, they set each pixel to have the same chromaticity as in the input. There will be a slight error in the chromaticities of the pixels that are clipped. Since the modified MSR is designed to preserve color, it did not grey out the image. It, therefore, did not require color restoration.

Hanumantharaju M. C, Ravishankar .M, Rameshbabu D. R and Ramachandran .S [22] proposed algorithm for multiscale retinex method based on modified color restoration. The original image of poor quality is read in RGB color space. The color channels are separated followed by the estimation of Gaussian surround function. SSR is obtained for each channel. Further MSR operation is carried out. Here the color restoration block is modified in such a way that the number of operations is reduced. To get the image pixel values in the standard unsigned range of 0 to 255, the MSR image is multiplied by a factor 28.44, followed by a positive offset of 128. An additional processing step is carried out in order to solve the gray world violation. Finally the gain-offset is applied to get an enhanced image.

Xinghao Ding, Xinxin Wang and Quan Xiao [23] proposed a color image enhancement algorithm based on human visual system based on adaptive filter. The algorithm utilizes color space conversion to obtain a much better visibility. The algorithm is effective in reducing halo and color distortion. The drawback is that the algorithm is not efficient from computation point of view.

SudharsanParthasarathy and Praveen Sankaran[24] propose that a fusion based approach on Multi Scale Retinex with Color Restoration would give better image enhancement. They choose wavelet based image fusion algorithms both for the ease of implementation and the high quality of fused mages. In DT-CWT based image fusion algorithm [25], first obtain match measure from the spatial domain information of the two images. Then take DT-CWT of both the images and then compute the activity measure from the wavelet domain coefficients. Next match measure and activity measure are combined using a linear combination and a decision map to create the MR decomposition of the fused image. The final step is to take inverse DT-CWT of the output of the previous step to get the fused image.

Hongqing Hu and Guoqiang Ni [26] came up with an improved retinex image enhancement algorithm. The algorithm provides good performance in color constancy, contrast and computational cost. The retinex based image enhancement is done in HSV color space rather than RGB space so an additional step is necessary to convert an image from RGB to HSV color space and from HSV to RGB space.

Ying Li, ChangzhiHou, Fu Tian, Hongli Yu, Lei Guo, GuizhiXu, XueqinShen, and Weili Yan [27] used the algorithms such as Frackle-McCann algorithm, McCann99 algorithm, SSR algorithm and MSR algorithm and applied to the enhancement of gray infrared image. The histogram equalization method is first used, and the image contrast is strengthened, but much detail in face is lost. By using Frackle-McCann Retinex algorithm [28], the luminance of image is obviously improved, but there is demi tint in the bright region. Using McCann99 Retinex algorithm, it seems more concordant than histogram equalization and it has less demi tint than Frackle-McCann Retinex algorithm. Using SSR algorithm can either achieve lightness rendition or dynamic range compression, but not both simultaneously. Finally, MSR algorithm is used and it produces a much better image, which has significant dynamic range compression in the boundary, and reasonable gray rendition in the whole image scale. MSR method is the best one for enhancement of infrared image. But the disadvantage is that noise removal is not possible.

Youhei Terai, TomioGoto, Satoshi Hirano, and Masaru Sakurai [29] came with retinex model for color image contrast enhancement. They processed the luminance signal to reduce the computation time without changing color components. The computation time of this approach is large due to large scale Gaussian filtering. So the algorithm performs better for gray images rather than color images, since color components are preserved.

Praveen Sankaran and SudharsanParthasarathy[30] propose an automated multi scale retinex with color restoration for image enhancement. They used an automated method to choose the upper and lower clipping points using two methods. The initial approach was to use variance as a control measure. But the conclusion is that the procedure of finding clipping points cannot be automated if variance is chosen as a control measure. Next method is by using the frequency of occurrence of pixels. This approach has removed the image dependency that the previous method has and this is a really great advantage in real time applications [31], [32] where the user would not have time to choose the optimum clipping points for a particular image.

Andrew F. Laine, Sergio Schuler, Jian Fan and Walter Huda [33] proposed enhancement of mammographic feature by multiscale analysis. They demonstrate that features extracted from multiresolution representations can provide an adaptive mechanism for accomplishing local contrast enhancement. They accomplish mammographic feature analysis through three multiresolution representations: the dyadic wavelet transforms [34], the Frazier- Jawerth transform (FJT) [35], and the hexagonal wavelet transform [36]. Contrast enhancement was applied to features of specific interest to mammography including masses, spicules and micro calcifications. Multiresolution representations provided an adaptive mechanism for the local emphasis of such features blended into digitized mammograms.

Lizhu Liu and Haiying Wang [37] proposed a Nonlinear Method to enhance images using improved single scale retinex algorithm. The method first uses a principal component analysis to the original image to provide orthogonality between channels and thus reduces the chromatic changes induced by the processing of luminance. Then a nonlinear method is applied to adjust the global dynamic range. Finally with an improved Sing-Scale Retinex algorithm whose filter shape is adapted to high-contrast edges of the image, the local contrast is increased without generating halo artifacts or washed-out problems.

Chen Shuyue and Zou Ling [38] presented an enhancement method based on multi-scale retinex to compress the dynamic range and enhance contrast for improving the visibility of the dark regions on chest radiograph. They used two-scale retinex with different weighted factors. First they determine standard deviations of Gaussian surround function and then convolution operations under two scales are done. Then calculate image output and finally stretch gray-level range.

Cui Lin-yan, Xue Bin-dang and Cao Xiao-guang[39] came up with Image enhancement based dim target extraction techniques. Firstly, the dim targets are enhanced through an improved retinex (MLIP_MSR) [40, 41] method. Secondly, the targets are roughly obtained by applying the relaxation iterative segmentation algorithm (RIS) [42], while part background is also retained, then the background filtering is used to remove the remained background. Finally the canny operator is applied to get the contour of the final dim targets and add it to the original image.

Liu yong and Yang ping xian [43] proposes a multi-dimensional multi-scale image processing algorithm which is based on multi-scale Retinex theory and combined a conduction function constructed. First, the input color image should be decomposed into three image components, and each component makes a double-precision conversion. Then each component separately does image smoothing and calculating of illumination spectrum estimates, and then in log domain the original image separately subtracts the part of the image smoothing and illumination spectrum. Then the components undergo conduction function treatment and MSR treatment. Next the two part of the component will be added, which make a log inverse conversion to get a single component images. Finally do of linear gray scale. At last three components synthesize a color image.

Ruibo Zhang, Yali Huang and Zhen Zhao [44] proposed a B-ultrasound image enhancement algorithm based on Multi-Scale Retinex theory. First step, image's gray function is obtained which contains component of irradiation beam and components of reflection. Second the logarithm method is used to separate irradiation beam components and reflection components. Third, if the irradiation beam is smooth, Gaussian template is used to do low-pass filter to original image, then filtered image is obtained. Fourth, in log-domain, use original image subtract low-pass filtered image, then high frequency image enhanced is obtained. Next repeat the step 3 and 4 to process the image with low pass filter. Finally, enhanced image is gotten by taking the exponential.Wei Ping, Li Junlit, Lu Dongming and Chen Gang [45] introduced a method which can prevent noise increasing during the sharpening of the image details. In this method, the original image is filltered by the hybrid low pass fillter which is designed according to local context of the image in order to remove out the impulse noise and no-impulse noise. Then the filtered image is decomposed into several band pass images. Each pixel in band pass image is adaptively assigned a different enhancement factor by evaluating the local feature. The processed band pass images can be composed into an enhanced image by the process opposite to the decomposition process.Min Zhang and XuanqinMou [46] proposed a novel nonlinear multi-scale enhancement algorithm for chest radiography. A novel nonlinear remapping function cooperated with human contrast sensitivity is brought into this architecture. There are three steps involved in the proposed technique. Initial step decomposes the radiograph into different sub bands from coarseness to detail. Then the local contrast map of radiographies is derived from the Weber contrast and cooperated into nonlinear remapping function. Finally the processed sub band images with nonlinear remapping are integrated into the reconstructed image.

Guodong Zhang, Donghong Sun, PeiyuYan, Hong Zhao and Zhezhu Li [47] described a novel image enhancement algorithm based on the single scale retinex theory to enhance the tiny anatomical structures and other regions of interest on the Low-dose CT images. This algorithm has three-stage, first separating the input images into illumination component and reflectance component, and calculating the approximate luminance of the original images. Next normalizing the illumination component for the image dynamic range adaptively and manipulating the reflectance component with a nonlinear function. Finally, combining the normalized illuminance with the Gamma corrected reflectance to obtain the results.

Li He, Ling Luo, and Jin Shang [48] described an image enhancement algorithm based on retinex theory that replaces brightness value of each pixel by the ratio of brightness value to the average values of the neighboring pixels. The enhancement based on retinex is suitable for images that are complicated, weakly illuminated, enlarged dynamic range.

Zia-ur Rahman, Glenn A. Woodell and Daniel J. Jobson [49] compare the MSRCR with color adjustment methods such as gamma correction and gain/offset application, histogram equalization, homomorphic filtering. Gain/offset correction is a linear operation and so has limited success on scenes that has a much wider dynamic range than that can be displayed. In this case, loss of detail occurs due to saturation and clipping as well as due to poor visibility in the darker regions of the image. Gamma correction is for providing dynamic range compression, but it is biased towards increasing the 'visibility' in the 'dark' regions by sacrificing the visibility in the 'bright' areas. Histogram equalization results in reassigning dark regions to brighter values and bright regions to darker values. It works well for perform well for a wide range of scenes, but they also fail for a large set. The homomorphic filter [50] consistently provided excellent dynamic range compression but is lacking in final color rendition. The output of the homomorphic filter in effect appears extremely hazy compared with the output of the MSRCR though the dynamic range compression of the two methods appears to be comparable. MSRCR have been chosen to maximize enhancement for a large number of images. Once the constants have been selected, then the process is truly automatic and independent of the variations in scene statistics.

Mrs. Anjali Chandra, BibhudendraAcharya and Mohammad Imroze Khan [3] have compared MSRCR with SSR and MSR. The SSR provides a good mechanism for enhancing certain aspects of images and providing dynamic range compression. Its limitation is that it can either provide good tonal rendition or dynamic range compression. The MSR overcomes the problem with SSR. But in both the approaches the color images get badly affected when the luminance portion of the image is passed through retinex. This problem was solved by MSRCR. MSRCR provides proportional RGB components in color images which is an improvement over MSR technique which is preferred for gray images. By the comparison of original image, SSR image, MSR image, MSRCR image and other image enhancement methods. Finally it is concluded that output of MSRCR is better than other techniques. Though some of the techniques work well for some images, only the MSRCR performs universally well on the test set.

Conclusion

The Retinex is one kind of image enhancement theory and it established at the scientific experiments and the scientific analysis. Comparing with conventional enhancement methods, the Retinex has shown itself to be a very versatile automatic method and can simultaneously provide sharpening, color constancy, dynamic range compression and color rendition. In the above section we have discussed about different algorithms, the most effective ones are 1) The light compensation algorithm which introduce FFT to make speed faster than the original retinex algorithm 2) In retinex model for color image contrast enhancement filtering is done using Gaussian filter so the algorithm performs better for grey images 3) Ultrasound images enhancement algorithm based on MSR is best for enhancing the ultrasound liver image.

Reference

1. E. Land (1986).An alternative technique for the computation of the designator in the retinex theory of color vision, in Proc. Nat. Acad. Sci., vol. 83, pp. 3078–3080.
2. Zia-ur Rahman, Glenn A. Woodell&Daniel J. Jobson (2001).Retinex Image Enhancement: Application to Medical Images, NASA Medical Imaging Conference Greenbelt, MD July 17.
3. Mrs. Anjali Chandra, BibhudendraAcharya&Mohammad Imroze Khan (2011).Retinex image processing: Improving the visual realism of color images, International Journal of Information Technology and Knowledge Management, Volume 4, No. 2, pp. 371-377
4. D. J. Jobson, Z. Rahman, & G. A. Woodell (1997).Properties and performance of a center/surround retinex, IEEE Trans. Image Processing, vol. 6, pp. 451–462, March.
5. Daniel.J. Jobsonz&Glenn A. Woodell (1995).Properties of a Center/Surround Retinex, NASA Langley Research Center, Hampton, Virginia 23681,August.
6. Zia-ur Rahmany, Daniel.J. Jobsonz&Glenn A. Woodell. Retinex Processing for Automatic Image Enhancement, College of William & Mary Department of Computer Science Williamsburg, VA 23187,NASA Langley Research Center, Hampton,Virginia 23681.
7. M. Herscovitz& O. Y. Pecht (2004).A modified Multi Scale Retinex algorithm with an improved global impression of brightness for wide dynamic range pictures, Machine Vision and Applications, no. 15, pp. 220-228, Aug.
8. D. J. Jobson, Z. Rahman, & G. A. Woodell (1996).Retinex Image Processing: Improved Fidelity to Direct Visual Observation, Proceedings of the IS&T/SID Fourth Colour Imaging Conference: Colour Science, Systems and Applications, Scottsdale, Arizona, November, pp. 124-126.
9. Jobson DJ, Rahman Z &Woodell GA (1997).A multiscale retinex for bridging the gap between color images and the human observation of scenes, IEEE Trans Image Process. 6(7):965-76. NASA Langley Res. Center, Hampton, V
10. Z. Rahman, D. Jobson & G. A. Woodell (1996).Multiscale retinex for color rendition and dynamic range compression, in Proc. SPIE 2847, Applications of Digital Image Processing XIX, A. G. Tescher, Ed.

11. A. Moore, J. Allman& R. M. Goodman (1991). A real-time neural system for color constancy, IEEE Trans. Neural Networks, vol. 2, pp. 237–247, March.
12. A. Moore, G. Fox, J. Allman& R. M. Goodman (1991). A VLSI neural network for color constancy, in Advances in Neural Information Processing 3, D. S. Touretzky and R. Lippman, Eds. San Mateo, CA: Morgan Kaufmann, pp. 370–376.
13. D. Brainard& B. Wandell (1986). Analysis of the Retinex theory of color vision, Journal of the Optical Society of America, Vol. 3, No. 10, pp. 1651-1661, October.
14. Yali Feng, Jing Huang, Zhuoli Feng &Minyong Liu (2011).The Research and Implementation of Light Compensation Algorithm in Color Facial Image, Electrical and Control Engineering Conference,pp.2758-2761
15. Yanxin Shi (2007). An Image Enhancement Algorithm Based on Retinex Theory, Electronic Science and Technology, Vol 12, pp.32-35, September.
16. Guanzhang Li, Qin Lu, WushengLuo& Pei Li (2010). Luminance-Chroma Nonlinear Recomposing of Color Image, Computer Engineering and Applications, Vol 25, pp.178-180, April.
17. Sun, Bo Tao, Wenjing Chen, Weifang Li, Hongyu Li, Jiang Guo&Wei, (2008). Luminance Based MSR for Color Image Enhancement, IEEE Image and Signal Processing, 358 – 362.
18. Junxuan Yan &Ke Zhang (2010).Adaptive Color Restoration and Luminance MSR Based Scheme for Image Enhancement, Advanced Computer Control International Conference, Vol. 3, pp. 185 – 188.
19. James F. Blinn (1993). NTSC: Nice Technology, Super Color, IEEE Computer Graphics & Applications, March.
20. Brian Funt, Kobus Barnard, Michael Brockington&VladCardei (1997).Luminance-Based Multi-Scale Retinex, May.
21. Funt, B., Cardei, V. & Barnard, K. (1996). Learning Colour Constancy, Proc. Fourth IS&T/SID Colour Imaging Conf., pp. 58-60, Scottsdale, Nov. 19-22..
22. Hanumantharaju M.C, Ravishankar .M, Rameshbabu D. R&Ramachandran .S (2011). Color Image Enhancement using Multiscale Retinex with Modified Color Restoration Technique, Emerging Applications of Information Technology International Conference, pp. 93-97.

23. Xinghao Ding, Xinxin Wang&Quan Xiao (2010). Color Image Enhancement with a Human Visual System based Adaptive Filter, Proceedings of International Conference on Image Analysis and Signal Processing, April.
24. SudharsanParthasarathy&Praveen Sankaran (2012). Fusion Based Multi Scale RETINEX with Color Restoration for Image Enhancement, International Conference on Computer Communication and Informatics.
25. Li Tao (2006). Old Dominion University, Multi modal Enhancement Techniques for visibility improvement of digital images, a Ph.D Dissertation.October.137 pages; 3219062
26. Hongqing Hu &Guoqiang Ni (2010).The improved algorithm for the defect of the Retinex Image Enhancement, Proceedings of International Conference on Anti-Counterfeiting Security and Identification in Communication (ASID), pp. 257-260, July.
27. Ying Li, ChangzhiHou, Fu Tian, Hongli Yu, Lei Guo, GuizhiXu, XueqinShen, &Weili Yan (2007). Enhancement of Infrared Image Based on the Retinex Theory, Proceedings of the IEEE, pp. 3315-3318.
28. B. Funt, F. Ciurea& J. McCann (2004).Retinex in Matlab, Journal of Electronic Imaging, vol. 13, no. 1, pp. 48-57, January.
29. Youhei Terai, TomioGoto, Satoshi Hirano&Masaru Sakurai (2009).Color Image Contrast Enhancement by Retinex Model, Proceedings of IEEE 13th International Symposium on Consumer Electronics, pp. 392-393, May.
30. SudharsanParthasarathy& Praveen Sankaran (2012). An Automated Multi Scale retinex with Color Restoration for Image Enhancement, IEEE.
31. W. J. Kyung, Y. H. Ha & D. C. Kim (2011).Real time Multi Scale Retinex to enhance night scene of vehicular camera, 17th Korea-Japan Joint Workshop on Frontiers of Computer Vision.
32. G. D. Hines, Zia-ur-Rahman, D. J. Jobson, G. A.Woodell& S. D. Harrah (2005). Real
time enhanced vision system, Proceedings of the SPIE, vol. 5802, pp. 127-134.
33. Andrew F. Laine, Sergio Schuler, Jian Fan &Walter Huda (1994).Mammographic Feature Enhancement by Multiscale Analysis, IEEE Transactions on medical imaging, vol 13.

34. S. Mallat& S. Zhong (1992).Characterization of signals from multi-scale edges, IEEE Transactions on Pattern Analysis and Ma- chine Intelligence, vol. 14, no. 7, pp. 710{732, July.
35. M. Frazier, B. Jawerth& G. Weiss (1991). Littlewood-paley theory and the study of function spaces, in Conference board of the mathematical sciences. Regional conference series in mathematics, number 79.
36. E.P. Simoncelli& E.H. Adelson (1990).Non-separable extensions of quadrature mirror filters to multiple dimensions, Proceedings of the IEEE, vol. 78, no. 4, pp. 652{664, April.
37. Lizhu Liu &Haiying Wang (2011).Image Enhancement Using a Nonlinear Method with an Improved Single-Scale Retinex Algorithm, Electronics Communications and Control International Conference.
38. Chen Shuyue&Zou Ling (2009). Chest Radiographic Image Enhancement Based on Multi-Scale Retinex Technique, Bioinformatics and Biomedical Engineering, 3rd International Conference.
39. Cui Lin-yan, Xue Bin-dang &Cao Xiao-guang (2009).An Improved Retinex Image Enhancement Technique for Dim Target Extraction in Infrared Images, Image and Signal Processing, CISP '09. 2nd International Conference, pp:1-5.
40. G.Deng&L.W.Cahill (1993).The Logarithm Image Processing Model and Its Applications, in Conference on. Signals, Systems and Computers, 1-3 November,vol.2, pp:1047 – 1051.
41. G.Deng, L.W.Cahill&G.R.Tobin (1995).The Study of Logarithmic Image Processing model and Its Application to Image Enhancement, IEEE Trans. Image Processing, vol.4, no.4, pp.506-512.
42. Michael W.Hansen& William E.Higgins (1997). Relaxation Method for Supervised Image Segmentation, IEEE Trans. Pattern Anal. March. IntelL, 1997, vol.19, no.9, pp.946-962.
43. Liu yong& Yang ping xian (2010). Multi-dimensional multi-scale image enhancement algorithm,Vol: 3, pp: V3-165 - V3-168.
44. Ruibo Zhang, Yali Huang & Zhen Zhao (2011).A Ultrasound Liver Image Enhancement AlgorithmBased on Multi-Scale Retinex Theory, Bioinformatics and Biomedical Engineering, (iCBBE)5th International Conference,pp:1-3.

45. Wei Ping, Li Junlit, Lu Dongming& Chen Gang (2006).A Multi-scale Enhancement Method to Medical Images Based on Fuzzy Logic, TENCON 2006, IEEE Region 10 Conference, pp:1-4.
46. Min Zhang &XuanqinMou (2008).Multi-scale nonlinear contrast enhancement of radiographies based on human contrast sensitivity, Visual Information Engineering, 2008, 5th International Conference, pp:513 – 517.
47. Guodong Zhang, Donghong Sun, Peiyu Yan, Hong Zhao &Zhezhu Li (2008). A LDCT Image Contrast Enhancement Algorithm Based on Single-scale Retinex Theory, Computational Intelligence for Modelling Control & Automation, 2008 International Conference, pp: 181 – 186.
48. Li He, Ling Luo& Jin Shang (2009).An Image Enhancement Algorithm based on Retinex Theory, Proceedings of First International Workshop on Education Technology and Computer Science, pp. 350-352, March.
49. Z. Rahman, D. Jobson &G. A. Woodell (1997). A Comparison of the Multiscale Retinex with Other Image Enhancement Techniques, NASA Langley Research Center.
50. T. G. Stockham, Jr (1972). Image processing in the context of a visual model, Proceedings of the IEEE, vol. 60, no. 7, pp. 828–842.